MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2008

Submitted to:

California Department of Fish and Game

By:

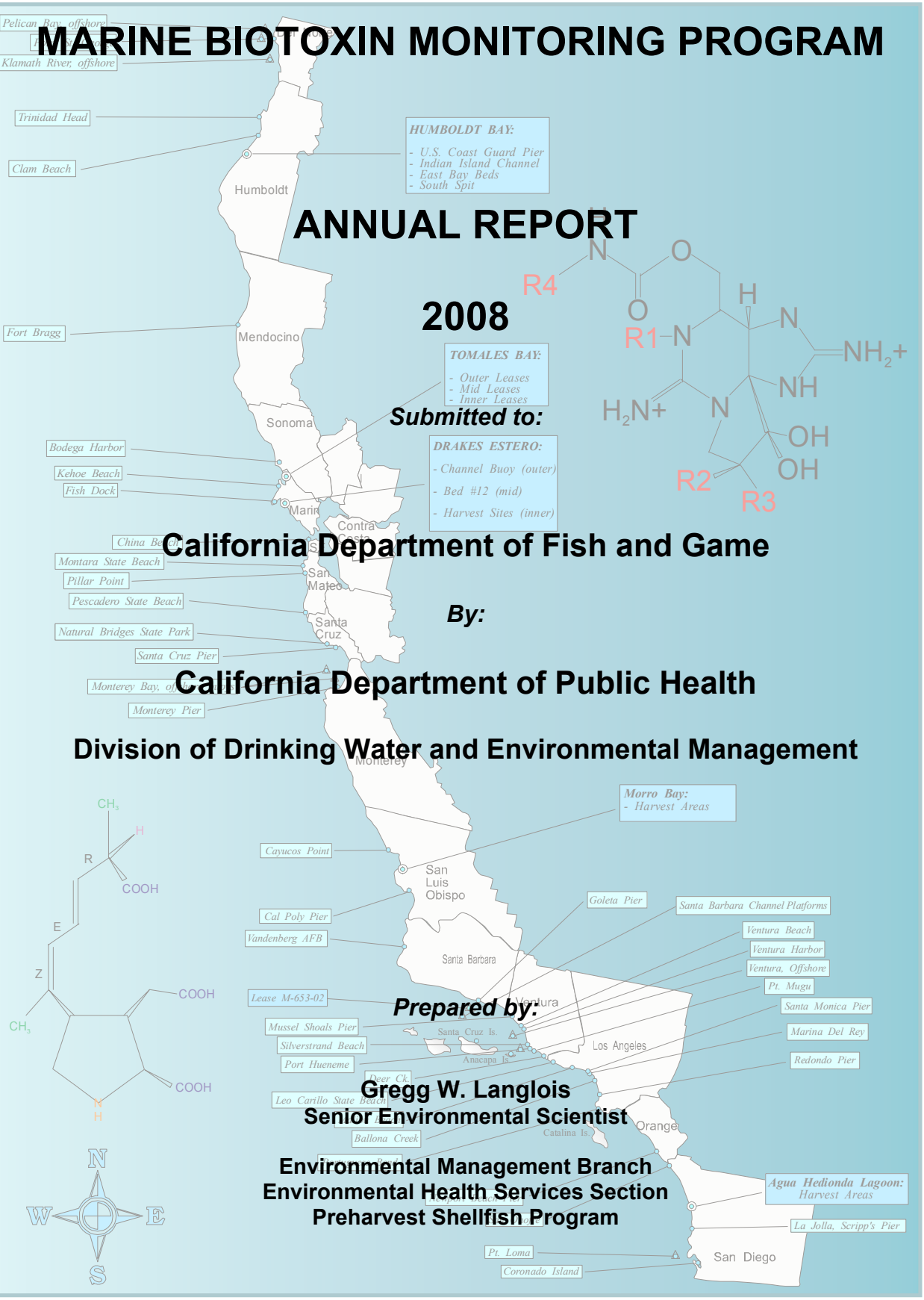
California Department of Public Health

Division of Drinking Water and Environmental Management

Prepared by:

Gregg W. Langlois
Senior Environmental Scientist

Environmental Management Branch
Environmental Health Services Section
Preharvest Shellfish Program



ACKNOWLEDGEMENTS

This report was prepared for the California Department of Fish and Game under agreement number P0770002. The California Department of Public Health would like to thank the Department of Fish and Game for their support of the paralytic shellfish poisoning monitoring portion of the marine biotoxin program.

The California Department of Public Health's Marine Biotoxin Monitoring Program would also like to acknowledge the dedicated work of the staff of the Department's Microbial Diseases Laboratory and the Food and Drug Laboratory for their efforts in conducting PSP assays and domoic acid analyses, respectively. Due to the unpredictable nature of marine biotoxin activity, the laboratories are often called upon to respond immediately to the influx of samples that result from these events. It is due to their efforts that we are able to provide rapid feedback to field samplers and notify the public of potential health risks.

Shellfish toxicity data is generated on a regular basis by the California Department of Public Health's Marine Biotoxin Monitoring Program thanks to the continuing efforts of our program participants. Additionally, volunteers are collecting phytoplankton samples on a routine basis and increase their frequency during periods of concern, providing near real-time observations of the occurrence of toxin producing species. As with all such endeavors, our success in protecting the public is due in large part to the numerous people who contribute their time and effort to collect samples at representative sites along the coast. The monthly listing of our program participants, provided in each monthly report, illustrates the diversity of groups and individuals that contribute to these efforts.

The California Department of Public Health expresses its sincere appreciation to our program participants for all of their efforts. It is through their active participation that the Department is able to protect and improve the health of all Californians.

TABLE OF CONTENTS

INTRODUCTION

California has a long history of paralytic shellfish poisoning (PSP), dating back to the time of the coastal Native American tribes. According to Meyer (1928) it was a common procedure for the coastal Pomo tribe to place sentries to watch for luminescence in the waves, having apparently established a link between bioluminescence and mussel poisoning, both of which are caused by dinoflagellates in the phytoplankton. The long-standing concern of California's public health officials for protecting the public from PSP has been warranted, as there have been 542 reported illnesses including 39 deaths attributable to this toxin since 1927 (Price et al., 1991).

In the fall of 1991 another natural toxin was identified along the California coastline. Domoic acid, a neurotoxin of lower potency than the PSP toxins, has become of concern because the blooms of diatoms that produce this toxin have been of greater frequency and longer duration than most PSP events over the past 10 years. In addition, domoic acid has had dramatic impacts on marine mammal and seabird populations along the coast, raising the public's awareness of marine biotoxins in general.

Because PSP toxicity represents a serious ongoing public health threat that requires year-round attention, the California Department of Public Health (CDPH) has implemented a prevention program that has traditionally been comprised of five basic elements: (1) a coastal shellfish monitoring program; (2) monitoring of commercial shellfish product; (3) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); (4) mandatory reporting of disease cases; and (5) public information and education activities. In response to the occurrence of a new toxin, domoic acid, in the fall of 1991, CDPH added a sixth element to the Marine Biotoxin Monitoring Program: phytoplankton monitoring. This effort was the first volunteer-based phytoplankton monitoring program in the U.S. This annual report describes the shellfish sampling element of the program for PSP toxins and domoic acid and the phytoplankton monitoring results during 2008. A summary is also provided for quarantine and health advisory activities.

Paralytic Shellfish Poisoning

PSP is an acute, sometimes fatal form of food poisoning that is associated with the consumption of bivalve molluscs that have fed on the toxin-producing dinoflagellate *Alexandrium catenella* (formerly *Protogonyaulax catenella* and *Gonyaulax catenella*). Eating shellfish that contain PSP toxins leads to an acute disturbance of the nervous system within a few minutes to a few hours. The PSP toxins are sodium channel blockers and thus inhibit neural transmission. Symptoms begin with tingling and numbness of the lips, tongue, and fingertips, followed by disturbed balance, lack of muscular coordination, slurred speech and difficulty in swallowing. In severe poisoning, complete muscular paralysis and death from asphyxiation can occur if breathing is not maintained by artificial means. There is no known antidote to the poison. Symptoms tend to resolve entirely in a day or two under proper medical care. Persons who

suspect they or others are experiencing PSP symptoms should immediately seek medical treatment.

The type and severity of symptoms depends on the amount of toxic shellfish consumed as well as the specific toxicity of the shellfish. Price et al. (1991) summarize the range of toxin dose responses as follows: 200 to 500 micrograms (µg) per 100 grams (g) of shellfish tissue will cause at least minor symptoms, 500 to 2000 µg will cause moderate to severe symptoms, and toxin concentrations greater than 2000 µg will produce serious to lethal effects. It should be noted that exceptions exist and serious health effects have also been documented at much lower concentrations (100 to 400 µg). The federal alert level for PSP toxicity is 80 µg/100 g of shellfish tissue, and the detection limit for the PSP bioassay is approximately 40 µg/100 g.

Alexandrium is normally absent or constitutes a minor component of the marine phytoplankton community along the California coast. Under favorable environmental conditions this dinoflagellate may undergo periods of rapid population growth, frequently referred to as a "bloom". The term "bloom" or "red tide" is misleading with respect to *Alexandrium* and the resultant PSP toxicity in shellfish. Visible blooms of *Alexandrium* are rarely seen along the California coast. Conversely, elevated levels of PSP toxins in shellfish can result from the presence of relatively low numbers of *Alexandrium* in the water.

The source of the dinoflagellates that provide the "seed" for such blooms is in question, but two likely scenarios are possible. First, resting cysts of *Alexandrium* in local sediments can, under favorable conditions, produce vegetative cells that can then reproduce both sexually and asexually, resulting in localized "hot spots" of PSP toxicity in shellfish. Second, this dinoflagellate may be transported in offshore warm water masses that can move onshore under certain environmental conditions. This advection process could potentially result in either a quick spike in PSP toxicity if the number of transported cells is high, or it may simply provide the cells necessary for a bloom to initiate. Regardless of the origins of the toxin-producing dinoflagellates, the general pattern has been for these blooms to be detected first along the open coast, occasionally followed by transport into bays and estuaries. The degree to which coastal phytoplankton blooms intrude into bays and estuaries is likely influenced in part by the orientation of the bay relative to coastal currents and by the extent of tidal mixing and transport that occurs inside the bay.

Domoic Acid

In October of 1991 the presence of another marine biotoxin was confirmed in California's coastal waters. Domoic acid toxicity, which can result in the condition called amnesic shellfish poisoning (ASP), was identified as the cause of death in a large number of brown pelicans and Brandt's cormorants in the Santa Cruz area of Monterey Bay. The birds had been feeding on schools of anchovies in the bay, which in turn had been feeding on a bloom of the diatom *Pseudo-nitzschia australis* (formerly *Nitzschia pseudoseriata*).

The only documented domoic acid event prior to 1991 was a serious episode in Prince Edward Island, eastern Canada, in 1987 in which three people died and over 100 people were made ill from the consumption of toxic mussels. Domoic acid is a neuroexcitatory amino acid that causes over-stimulation of certain nerves cells in the brain, with potentially permanent or fatal effects. Case studies of the Canadian episode indicated that the most common symptoms were gastrointestinal, followed by neurologic symptoms including headaches, loss of balance and/or dizziness, memory loss, varying degrees of confusion, disorientation, changes in the level of consciousness, and in some cases seizures (Teitelbaum, 1990; Perl et al., 1990).

Based on the rather small number of case histories available the following dose responses can be approximated while recognizing the overlap in ranges and symptoms: 27 to 75 µg/g may result in mild to moderate symptoms (gastrointestinal), 40 to 700 µg/g may result in moderate to severe neurologic symptoms, and domoic acid concentrations greater than 450 µg/g may result in severe neurologic symptoms and/or death.

Phytoplankton

There were no documented human health impacts from the 1991 Monterey Bay domoic acid episode, but the severity of the Canadian outbreak made it clear that continued monitoring for domoic acid would be necessary for public health protection. Because of the cost and time involved in running separate analyses for each toxin, in addition to the prospect that other known toxins may be present along the California coast, CDPH began a volunteer-based phytoplankton monitoring program in 1993 with the technical support of the U.S. Food and Drug Administration. The intent of this program was to develop a network of volunteer samplers and field observers that would allow the early detection of potentially toxigenic blooms. Early detection is key to mobilizing and focusing additional sampling and analytical resources for plankton, shellfish, and other species in the affected region. As a result of this volunteer effort CDPH has been able to detect and track numerous harmful algal blooms, improving the capabilities for protecting public health.

2008 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 80 different sites along the coast of California in 2008 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1262 shellfish samples collected statewide for PSP toxin assay during 2008. The greatest number of samples (459) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 83% of the samples collected in this county. The majority of these (240) were contributed by Drakes Bay Oyster Company in Drakes

Estero, which samples four stations on at least a weekly basis. The large proportion of Marin County sites is a reflection of both the number of commercial growers and the frequency of occurrence of PSP toxicity in this region.

Commercial shellfish growers accounted for 68% of all samples collected in 2008, followed by various state agencies and coastal county health departments (21% and 8%, respectively; Table 2). Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2008. The diversity of participants is a valuable component of the monitoring program (Table 3). As mentioned above, monitoring of the outer coast is a key element in California's marine biotoxin monitoring program because all toxic blooms to date have originated offshore or along the coast. Monitoring coastal shellfish resources can therefore provide an early warning of toxic conditions that may soon impact shellfish in bays and estuaries, which harbor the majority of commercial shellfish growers and recreational clam beds.

The majority of samples collected in 2008 consisted of mussels (69%), followed by pacific oysters (29%; Table 4). A variety of other species of shellfish were sampled for PSP toxin analysis in 2008, including several genera of clams and crustaceans. The Marine Biotoxin Monitoring Program continues to use mussels as a primary indicator species for PSP toxins because of their ability to bioaccumulate these toxins at a faster rate that other bivalve species (Shumway, 1990). Differential uptake in mussels versus oysters during a major PSP event in 1991 was previously documented (California Department of Health Services, 1991).

Domoic Acid

There were 323 shellfish samples analyzed for domoic acid during 2008 compared to 351 samples analyzed the previous year (Table 5). Samples from 49 different sampling sites were targeted for analysis as a result of observations from the volunteer monitoring network of high numbers of *Pseudo-nitzschia spp*. The greatest numbers of samples were submitted from Santa Barbara County (89) and San Luis Obispo County (77).

Phytoplankton

There were 1696 phytoplankton samples collected during 2008, close to the record-setting number of annual samples submitted last year (1741) by our volunteer-based monitoring effort. These samples were collected at 137 sampling sites representing all coastal counties (Table 6). The greatest numbers of samples were collected in San Luis Obispo (344), Marin (256), and Santa Barbara (239) counties. Samples were collected along all coastal counties by 79 volunteers (Figures 1c and 1d). Several areas (e.g., commercial shellfish growing areas) had multiple sites that are not individually identified in the figure and some volunteers sample sites in multiple counties.

Of the 1696 phytoplankton samples collected in 2008, 1071 (63%) contained at least

one toxigenic species. Toxin-producing phytoplankton species were detected at 122 different sampling sites throughout all of the 15 coastal counties in 2008. The greatest numbers of samples containing toxin-producing species were collected in San Luis Obispo (244), Santa Barbara (164), and Marin (128) counties.

2008 RESULTS

Paralytic Shellfish Poisoning Toxicity and *Alexandrium* Observations

The geographic distribution of PSP toxins in shellfish during 2008 was slightly broader than that of 2007, although the magnitude of PSP toxicity was slightly less (Figure 2). There were fewer samples above the alert level, distributed throughout a greater number of counties, than occurred in 2007. Measurable concentrations of PSP toxins were found in 135 shellfish samples from the following coastal counties: Del Norte, Humboldt, Sonoma, Marin, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, and San Diego (Table 7). Low levels of these toxins were detected in every month of 2008. The general increase in PSP activity along most of the southern California coast, noted in 2006 and 2007, was documented again in 2008. Of note was the reoccurrence of high concentrations of the PSP toxins in samples at Santa Barbara sites in 2008, a pattern that began in 2004.

PSP toxin concentrations at or above the alert level were detected in 10 samples from Marin (6), Santa Barbara (3), and San Diego (1). PSP toxicity was found most frequently along the coast of Marin County during 2008. The highest toxin concentrations detected in 2008 was 293 µg/100 g of shellfish meat in sentinel sea mussels from Drakes Estero (Marin County) and 283 µg in mussels from an offshore aquaculture lease in Santa Barbara County.

The temporal distribution of PSP toxins in 2008 was unusual compared to the typical average annual pattern. There was an early winter peak in activity in Santa Barbara, an event that initiated in December 2007 (Figure 3). There was also a significant lack of PSP activity at northern California sites in the first half of the year, unusual particularly for sites in Marin County that have traditionally experienced a spring increase in toxicity.

Alexandrium was present at varying levels along the southern California coastline throughout 2008 (Figure 4), although the numbers and geographic distribution declined significantly after July. Consistent with the presence of *Alexandrium*, low concentrations of PSP toxin levels were persistent in shellfish throughout this period of time at one or more sites in southern California. As mentioned previously, concentrations of PSP toxins exceeding the alert level were detected in early January in Santa Barbara. Low levels of these toxins were also detected in shellfish samples from San Luis Obispo and Ventura counties in January. By the third week in February PSP toxins were detected in shellfish from Agua Hedionda Lagoon (San Diego County). The toxin concentration exceeded the alert level at this site by the last week in March (114 µg) then quickly declined, persisting at low levels through April. This is the first known occurrence of

PSP toxin concentrations exceeding the alert level inside this lagoon.

As the abundance and distribution of *Alexandrium* declined between San Luis Obispo and San Diego counties, there was an increase in this dinoflagellate in northern California sites. An increase in the relative abundance of *Alexandrium* in August was associated with the presence of PSP toxins in shellfish samples from Marin and Humboldt counties by mid month. PSP toxicity exceeded the alert level in Drakes Estero (200 µg) by the third week of August and in Drakes Bay (99 µg) by the fourth week. The elevated levels of PSP toxins in Drakes Estero persisted through the third week of September, declining through October. Low levels of these toxins persisted at sites in Humboldt County through November and in Del Norte County through the second week of December.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

Measurable concentrations of domoic acid were found in 38 samples during 2008 (Table 8), compared to 80 positive samples in 2007. Domoic acid was detected in samples from the following coastal counties: Del Norte, Humboldt, Sonoma, Marin, Santa Cruz, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, and San Diego. Concentrations of domoic acid above the alert level (20 µg per gram of shellfish meat, or 20 parts per million (ppm)) were detected in only one sample of lobster viscera that was collected near Anacapa Island on December 31.

The magnitude of domoic acid toxicity in 2008 was much lower than observed in 2007, however this toxin was detected in samples from a greater number of counties. The majority of positive samples came from southern California counties, with sites in Santa Barbara and Ventura experiencing the highest number of positive samples. The low levels of domoic acid persisted for approximately three months in samples from the southern California region, beginning in late February and continuing through the end of May (Figure 5). A rare occurrence of this toxin was detected in samples from Marin and Sonoma counties in late August following an observed increase in *Pseudo-nitzschia* in this region. Although the toxin concentrations did not exceed 5 ppm, it has been five years since the last positive sample in this region.

The highest percent composition of *Pseudo-nitzschia* was observed in early August in Crescent City (Del Norte County), although the sample appeared to be composed mostly of a nontoxic species in the *delicatissima* complex of this genus. Other high percentages of *Pseudo-nitzschia* were observed in San Luis Obispo in early May (80%), Ventura and Los Angeles in April (70%), and Sonoma and Santa Cruz in August (70%).

The percent composition data for *Pseudo-nitzschia* can be misleading. To adjust for the importance of cell mass, as well as sampling effort, a Relative Abundance Index (RAI) was formulated. The RAI is based on an estimate of cell mass as determined by settled cell volume (a), the percent composition of each species (b), and the sampling effort as determined by the total tow length (c):

$$RAI = (a*b)/c$$

The RAI data can provide perspective on the significance of the percent composition data for *Pseudo-nitzschia* or other species of interest. Many of the observations of high percentages of *Pseudo-nitzschia* (Figure 6) have less importance when the RAI is determined (Figure 7). Based on the percent composition data there were two peak periods of *Pseudo-nitzschia* abundance, a spring and a fall increase, which coincide with the periods of positive domoic acid samples (Figure 6). The period of maximum RAI values for *Pseudo-nitzschia* observations during 2008 (Figure 7) occurred in the spring, which is in agreement with the period of highest domoic acid concentrations in shellfish samples (Figure 5).

Detailed maps illustrating the weekly relative domoic acid and PSP toxin concentrations for each month, the monthly distribution and relative abundance of *Alexandrium* and *Pseudo-nitzschia*, and the monthly lists of program participants are provided in separate monthly reports. These reports are available at the following Internet site:

http://www.cdph.ca.gov/healthinfo/environhealth/water/Pages/Shellfish.aspx

2008 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

The State Public Health Officer issued the annual quarantine on the sportharvesting of mussels on May 1 as scheduled. The annual mussel quarantine applies only to sport-harvested mussels along the entire California coastline, including all bays and estuaries. Routine biotoxin monitoring is maintained throughout this period. The annual quarantine does not affect the certified commercial shellfish growing areas in California. Shellfish sold by certified harvesters and dealers are subject to frequent mandatory testing.

The annual quarantine on the sport-harvesting of mussels was rescinded on midnight, October 31, as scheduled. There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2008.

REFERENCES

California Department of Public Health Marine Biotoxin Monitoring Program, 1991. "Shellfish biotoxin monitoring program annual report, 1991", 50 pp.

Meyer, K.F.; Sommer, H.; Schoenholz, P. 1928. "Mussel Poisoning", J. Prevent. Medicine, 2:365 – 394.

Perl, T.M.; Bedard, L.; Kosatsky, T. Hockin, J.C.; Todd, E.C.D.; McNutt, L.A.; Remis, R.S. 1990. "Amnesic shellfish poisoning: a new clinical syndrome due to domoic acid", In: "Proceedings of a Symposium, Domoic Acid Toxicity", Canada Diseases Weekly Report, Vol. 16S1E, 123 pp.

Price, D.W.; Kizer, K.W.; Hansgen, K.H. 1991. "California's paralytic shellfish poisoning prevention program, 1927 – 89", *J. Shellfish Res.*, 10:119 -145.

Shumway, S. E. 1990. "A review of the effects of algal blooms on shellfish and aquaculture", J. World Aquaculture Soc., 21: 65 – 104.

Teitelbaum, J. 1990. "Acute manifestations of domoic acid poisoning: Case presentations", In: "Proceedings of a Symposium, Domoic Acid Toxicity", Canada Diseases Weekly Report, Vol. 16S1E, 123 pp.

TABLES 1 – 7

Table 1. Total number of shellfish samples collected per coastal county in 2008 for PSP assay.

COUNTY	# SAMPLES
Del Norte	17
Humboldt	115
Mendocino	4
Sonoma	6
Marin	459
San Francisco	6
San Mateo	19
Santa Cruz	52
Monterey	7
San Luis Obispo	254
Santa Barbara	165
Ventura	27
Los Angeles	30
Orange	10
San Diego	91
TOTAL	**1262**

Table 2. Number of shellfish samples collected by program participants, per coastal County, in 2008 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	13	4	--	--	17
Humboldt	103	8	3	--	1	115
Mendocino	--	4	--	--	--	4
Sonoma	--	--	6	--	--	6
Marin	380	--	78	--	1	459
San Francisco	--	6	--	--	--	6
San Mateo	--	16	--	--	3	19
Santa Cruz	--	2	50	--	--	52
Monterey	--	--	7	--	--	7
San Luis Obispo	206	--	47	--	1	254
Santa Barbara	109	--	50	6	--	165
Ventura	--	17	--	2	8	27
Los Angeles	--	29	--	--	1	30
Orange	--	10	--	--	--	10
San Diego	62	--	16	--	13	91
TOTAL =	**860**	**105**	**261**	**8**	**28**	**1262**

Table 3. Program participants by county that submitted shellfish samples in 2008 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
	California Department of Fish and Game
Humboldt	Coast Seafoods Company
	California Department of Fish and Game
	Humboldt County Environmental Health Department
	Humboldt State University Marine Lab
Mendocino	Mendocino County Environmental Health Department
Sonoma	CDPH Volunteer
	CDPH Marine Biotoxin Monitoring Program
Marin	CDPH Volunteer
	Cove Mussel Company
	Drakes Bay Oyster Company
	CDPH Marine Biotoxin Monitoring Program
	Hog Island Oyster Company
	Marin Oyster Company
	Calif. Program for Regional Enhanced Monitoring of PhycoToxins
	Tomales Bay Oyster Company
San Francisco	San Francisco County Health Department
San Mateo	San Mateo County Environmental Health Department
	CDPH Volunteer
Santa Cruz	Santa Cruz County Environmental Health Department
	University of California Santa Cruz
	Calif. Program for Regional Enhanced Monitoring of PhycoToxins
Monterey	University of California Santa Cruz
San Luis Obispo	CDPH Volunteer
	Calif. Program for Regional Enhanced Monitoring of PhycoToxins
	Tomales Bay Oyster Company
	Williams Shellfish Company
Santa Barbara	Santa Barbara Mariculture Company
	University of California Santa Barbara
	Vandenberg Air Force Base, Environmental Health Services
Ventura	Ventura County Environmental Health Department

	CDPH Volunteer
	Naval Air Station, Pt. Mugu
Los Angeles	Los Angeles County Health Department
	CDPH Volunteer
Orange	Orange County Health Care Agency
San Diego	Carlsbad Aquafarm, Inc.
	CDPH Volunteer
	Scripps Institute of Oceanography

Table 4. Number and species of samples collected in 2008 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[1]:	
Sentinel	86
Wild	5
Cultured	228
Total Bay Mussels	***319***
Sea Mussels[2]:	
Sentinel	364
Wild	180
Total Sea Mussels	***544***
Mixed Bay and Sea Mussels	3
Total Mussels	**866**
Pacific Oysters[3]	
Cultured	**326**
Sentinel	**37**
Total Oysters	**363**
Other[4]	**33**
TOTAL	**1262**

[1] *Mytilus galloprovincialis or M. trussulus*
[2] *Mytilus californianus*
[3] *Crassostrea gigas*
[4] *Razor clam, Washington clam, Gaper clam, Littleneck clam, Pismo clam, Dungeness crab, Spiny Lobster*

Table 5. Total number of shellfish samples analyzed for domoic acid, per coastal county, in 2008.

COUNTY	# SAMPLES
Del Norte	7
Humboldt	7
Mendocino	0
Sonoma	3
Marin	44
San Francisco	1
San Mateo	1
Santa Cruz	44
Monterey	6
San Luis Obispo	77
Santa Barbara	89
Ventura	14
Los Angeles	10
Orange	2
San Diego	18
TOTAL	**323**

Table 6. Total number of phytoplankton samples collected per coastal county in 2008.

COUNTY	# SAMPLES
Del Norte	33
Humboldt	81
Mendocino	12
Sonoma	20
Marin	256
Contra Costa	3
San Francisco	68
San Mateo	126
Santa Cruz	102
Monterey	71
San Luis Obispo	344
Santa Barbara	239
Ventura	82
Los Angeles	122
Orange	32
San Diego	105
TOTAL	**1696**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2008.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
01/02/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	72
01/02/08	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	67
01/02/08	Ventura	Sea Mussel, wild	Pt. Mugu	47
01/03/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	155
01/07/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	283
01/07/08	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	98
01/08/08	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	46
01/09/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	40
01/14/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	70
01/14/08	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	50
01/15/08	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	42
01/16/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	44
01/17/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	66
01/17/08	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	44
01/28/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	51
01/31/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	38
FEBRUARY				
02/06/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	36
02/17/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	42
02/18/08	Ventura	Lobster, Spiny, viscera	Ventura, Port Hueneme Pier	44
02/20/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	39
02/20/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	41
02/21/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	47
02/25/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	46
02/26/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	45
02/27/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	41
02/27/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	42

MARCH				
03/02/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	50
03/04/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	40
03/05/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	41
03/05/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	67
03/06/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	57
03/10/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	43
03/10/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	41
03/10/08	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	44
03/11/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	46
03/12/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	38
03/17/08	Orange	Sea Mussel, wild	Newport Beach Pier	36
03/17/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	40
03/18/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	37
03/24/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	50
03/24/08	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	41
03/25/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	72
03/26/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	47
03/26/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	46
03/27/08	Los Angeles	Sea Mussel, wild	Portuguese Bend	74
03/27/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	52
03/31/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	114
APRIL				
04/01/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	70
04/02/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	39
04/02/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	40
04/03/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	73
04/03/08	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	38
04/05/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	74
04/07/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	74
04/09/08	Orange	Sea Mussel, wild	Newport Beach Pier	57
04/09/08	San Diego	Littleneck Clam	San Onofre-CLLN	49

04/10/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	36
04/10/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	51
04/14/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	42
04/14/08	San Diego	Lobster, Spiny, viscera	San Diego, Pt. Loma	36
04/16/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	36
04/16/08	Los Angeles	Sea Mussel, wild	Portuguese Bend	41
04/21/08	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon-M	40
04/22/08	Los Angeles	Sea Mussel, wild	Santa Monica Pier	43
04/30/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	37
MAY				
05/01/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	48
05/21/08	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	36
05/22/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	38
05/22/08	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	36
05/28/08	Santa Barbara	Sea Mussel, wild	Goleta Pier	37
05/29/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	42
JUNE				
06/05/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	46
06/11/08	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	41
JULY				
07/07/08	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	41
07/14/08	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	36
AUGUST				
08/18/08	Marin	Sentinel Pacific Oyster	Drakes Bay, Fish Dock	41
08/18/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	42
08/19/08	Humboldt	Sea Mussel, wild	Trinidad Head	41
08/19/08	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	44
08/19/08	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #8	41
08/19/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	200
08/21/08	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	40
08/21/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	75
08/22/08	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	41

08/25/08	Marin	Sentinel Pacific Oyster	Drakes Bay, Fish Dock	75
08/25/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	99
08/26/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	63
08/26/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	293
08/28/08	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	48
08/28/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	78
08/28/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
SEPTEMBER				
09/02/08	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	38
09/02/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	74
09/02/08	Marin	Sentinel Pacific Oyster	Drakes Bay, Fish Dock	46
09/02/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	78
09/02/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	99
09/04/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	40
09/04/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
09/08/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	50
09/08/08	Marin	Sentinel Pacific Oyster	Drakes Bay, Fish Dock	50
09/09/08	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	40
09/09/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	48
09/09/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	105
09/10/08	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	51
09/11/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	54
09/11/08	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	36
09/11/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	69
09/12/08	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	40
09/14/08	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	40
09/15/08	Marin	Sentinel Pacific Oyster	Drakes Bay, Fish Dock	37
09/15/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	44
09/16/08	Humboldt	Sea Mussel, wild	Trinidad Head	52
09/16/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	99
09/16/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	40
09/17/08	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	36

09/18/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	50
09/18/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	43
09/22/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	36
09/23/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	38
09/30/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	39
09/30/08	Humboldt	Sea Mussel, wild	Trinidad Head	38
OCTOBER				
10/07/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	38
10/07/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	34
10/21/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
10/28/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	37
10/28/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	65
10/28/08	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	33
10/28/08	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
NOVEMBER				
11/04/08	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
11/12/08	Del Norte	Sea Mussel, wild	Point St. George	57
11/21/08	Ventura	Lobster, Spiny, viscera	Ventura, Port Hueneme Pier	37
11/24/08	Humboldt	Sea Mussel, wild	Trinidad Head	35
DECEMBER				
12/08/08	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	38
12/10/08	Del Norte	Sea Mussel, wild	Point St. George	39
12/31/08	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., West	37

FIGURES 1 – 13.

Figure 1a. Locations of shellfish sampling stations during 2008 (Del Norte to Monterey counties).

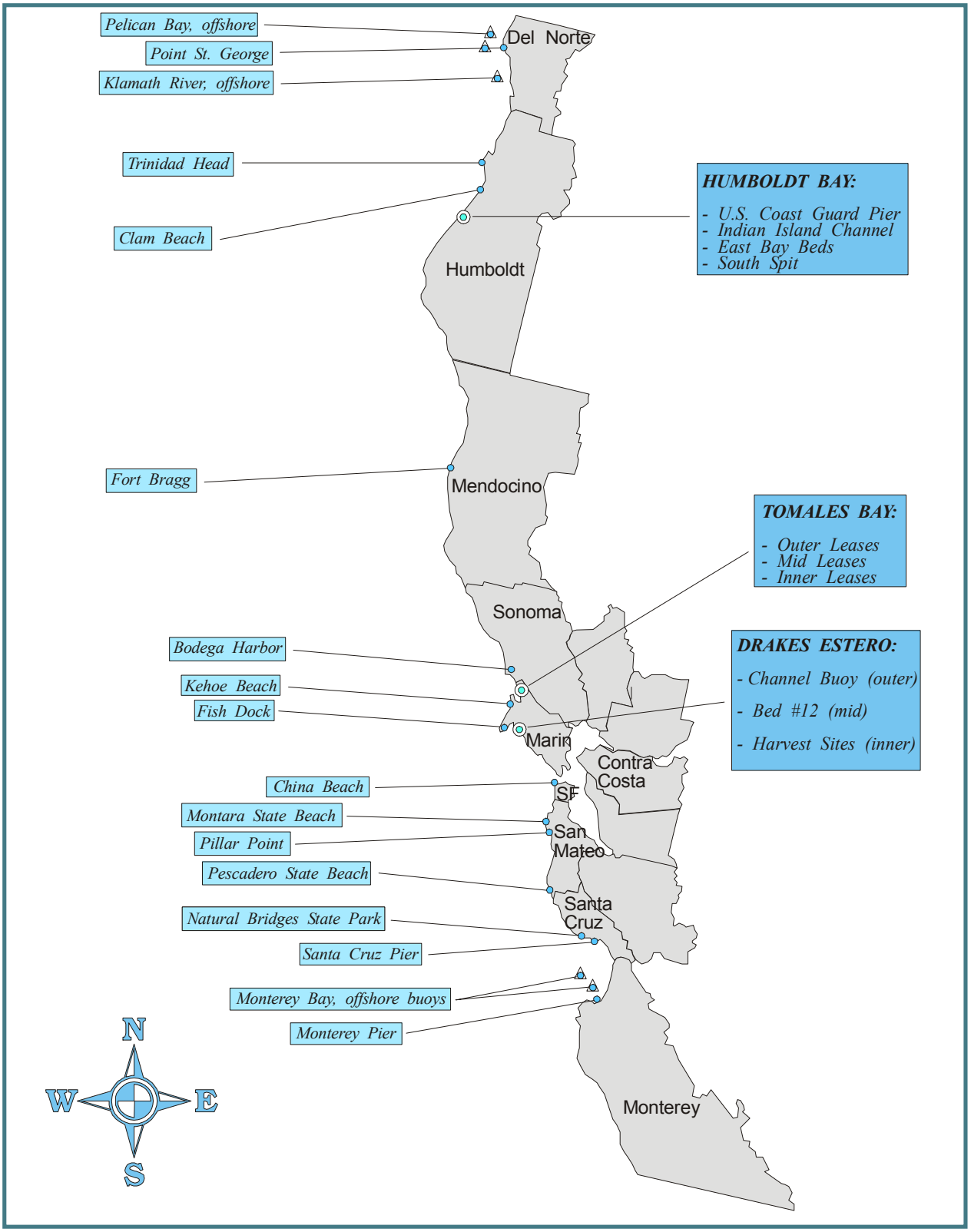


Figure 1b. Locations of shellfish sampling stations during 2008 (San Luis Obispo to San Diego counties).

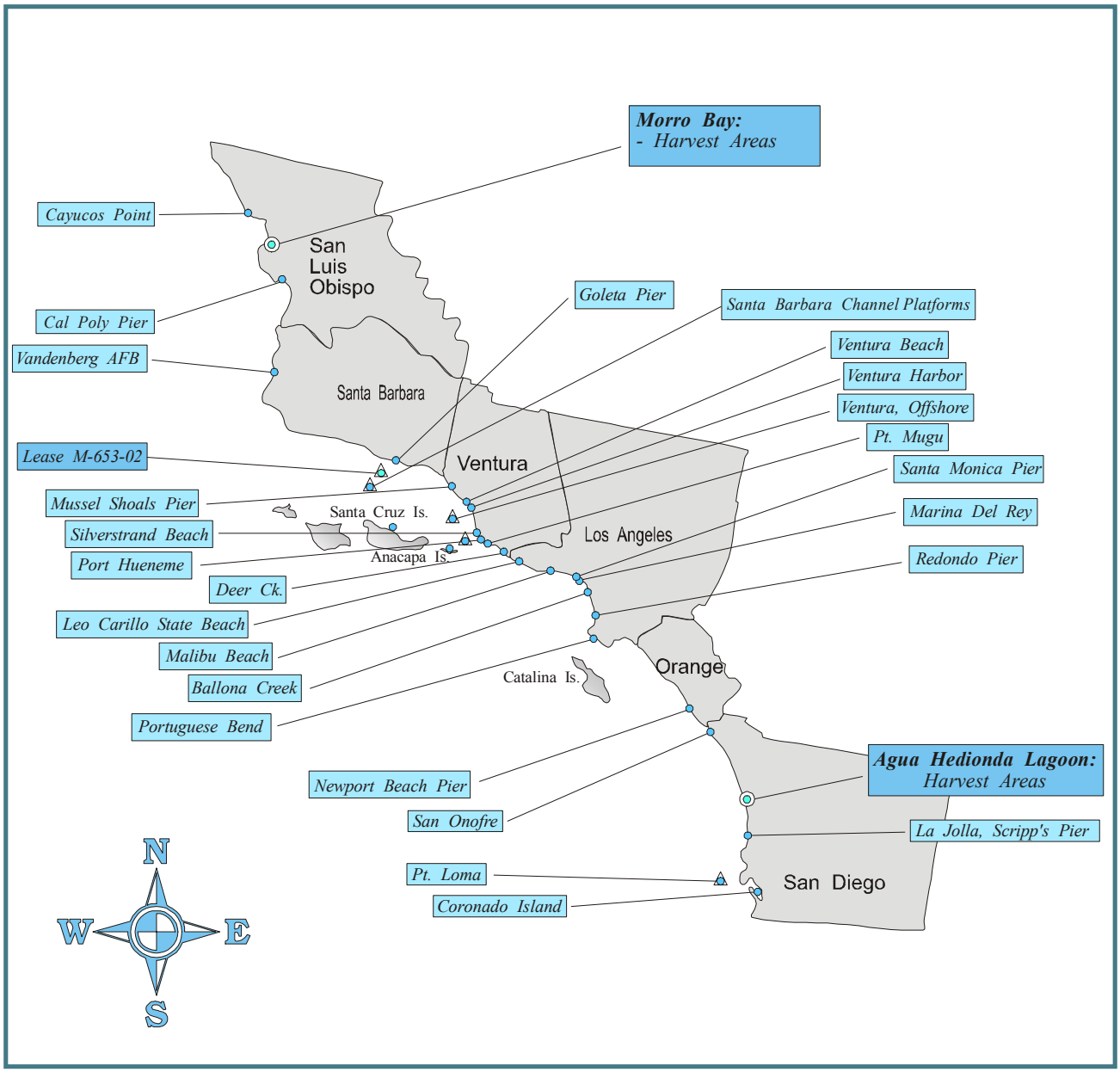


Figure 1c. Locations of phytoplankton sampling stations during 2008 (Del Norte to Monterey counties).

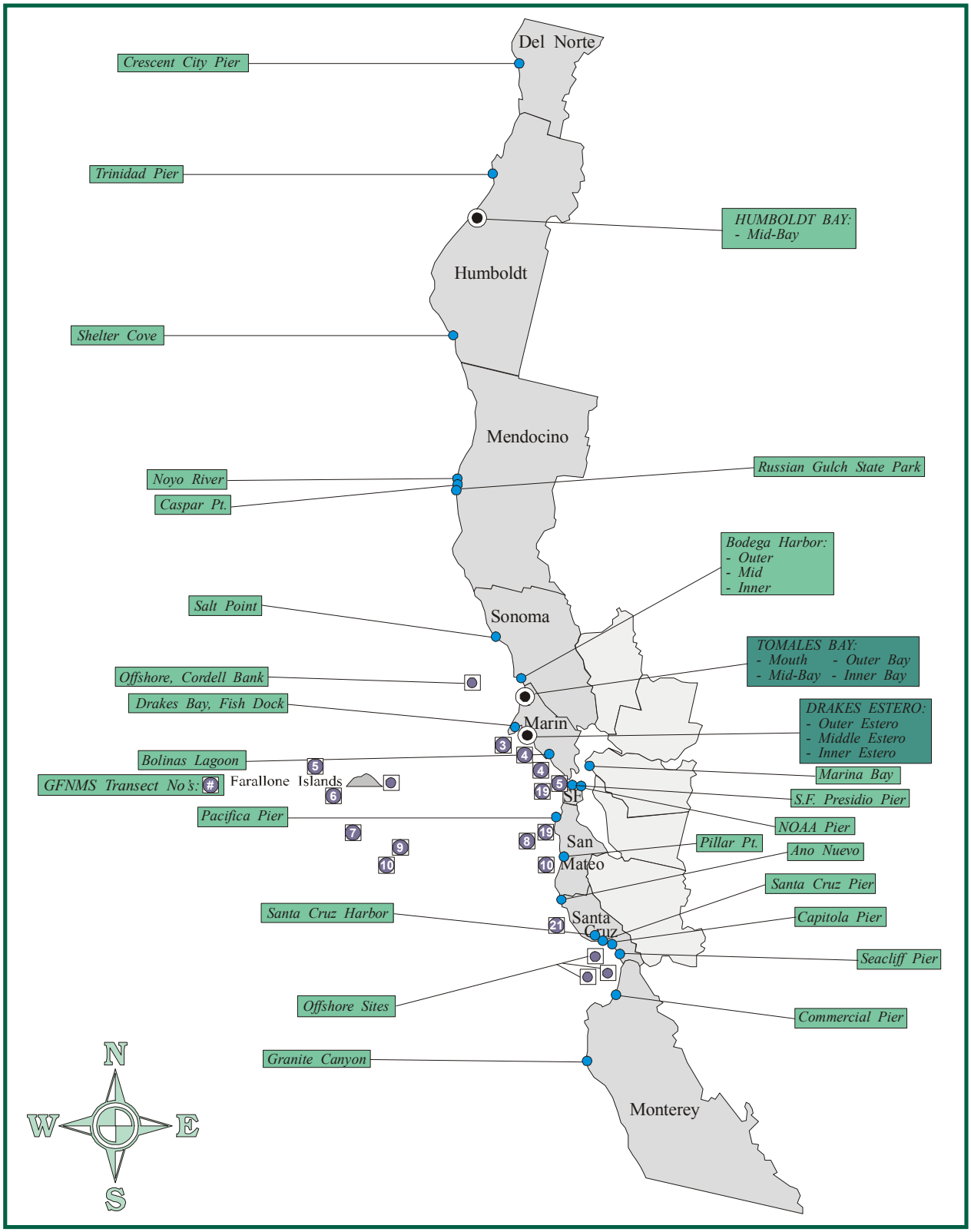


Figure 1d. Locations of phytoplankton sampling stations during 2008 (San Luis Obispo to San Diego counties).

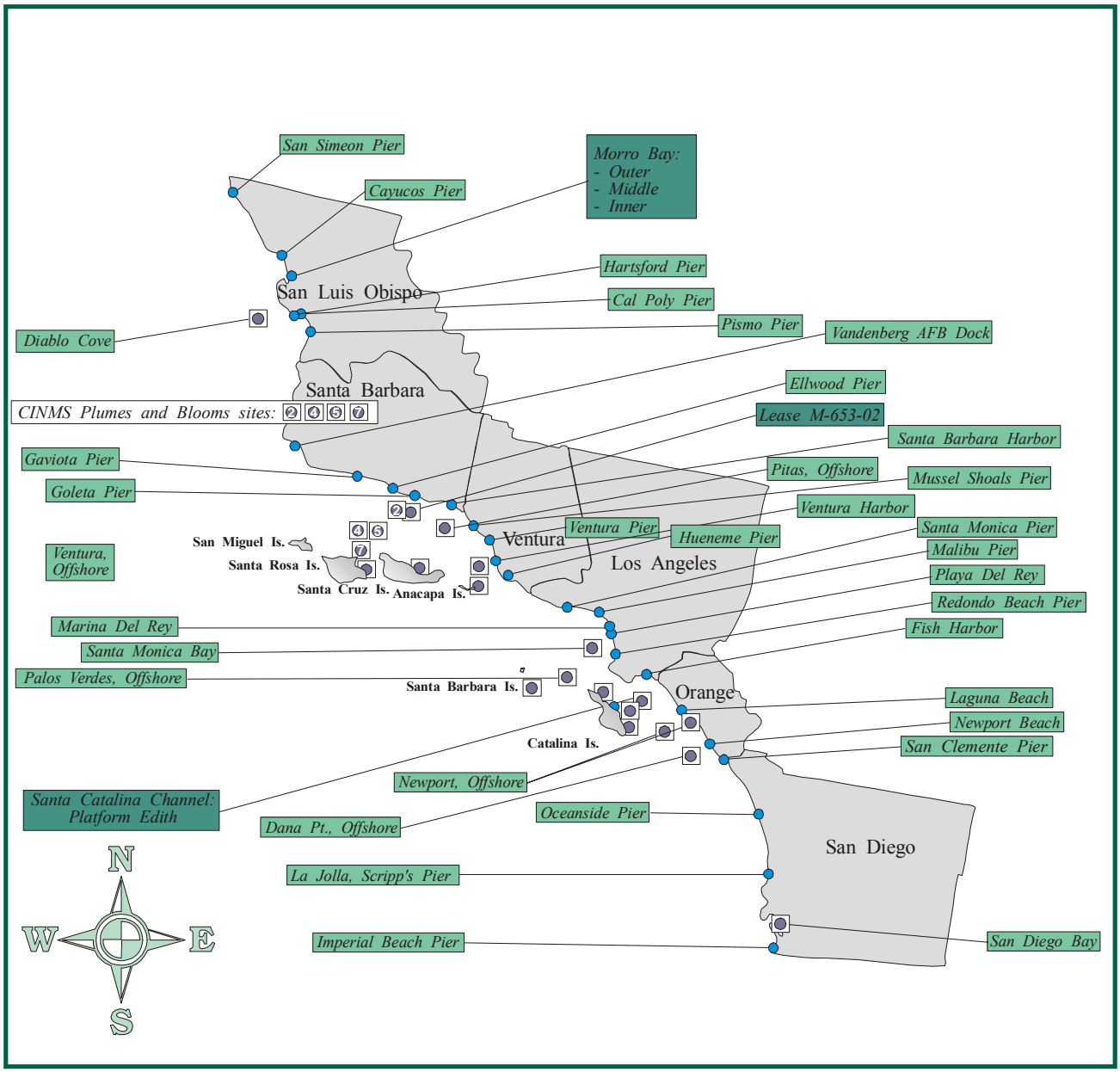


Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2008.

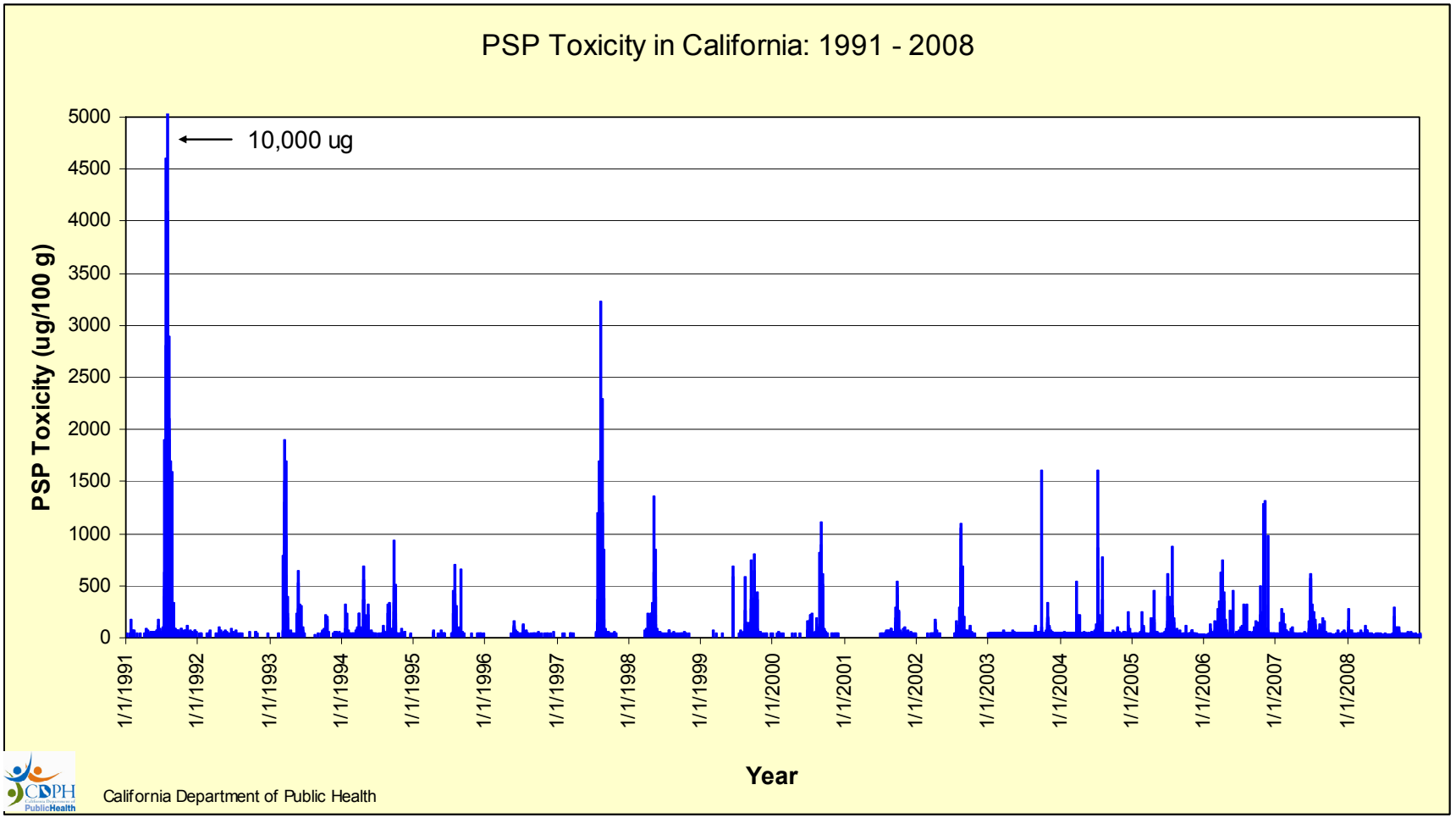


Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2008.

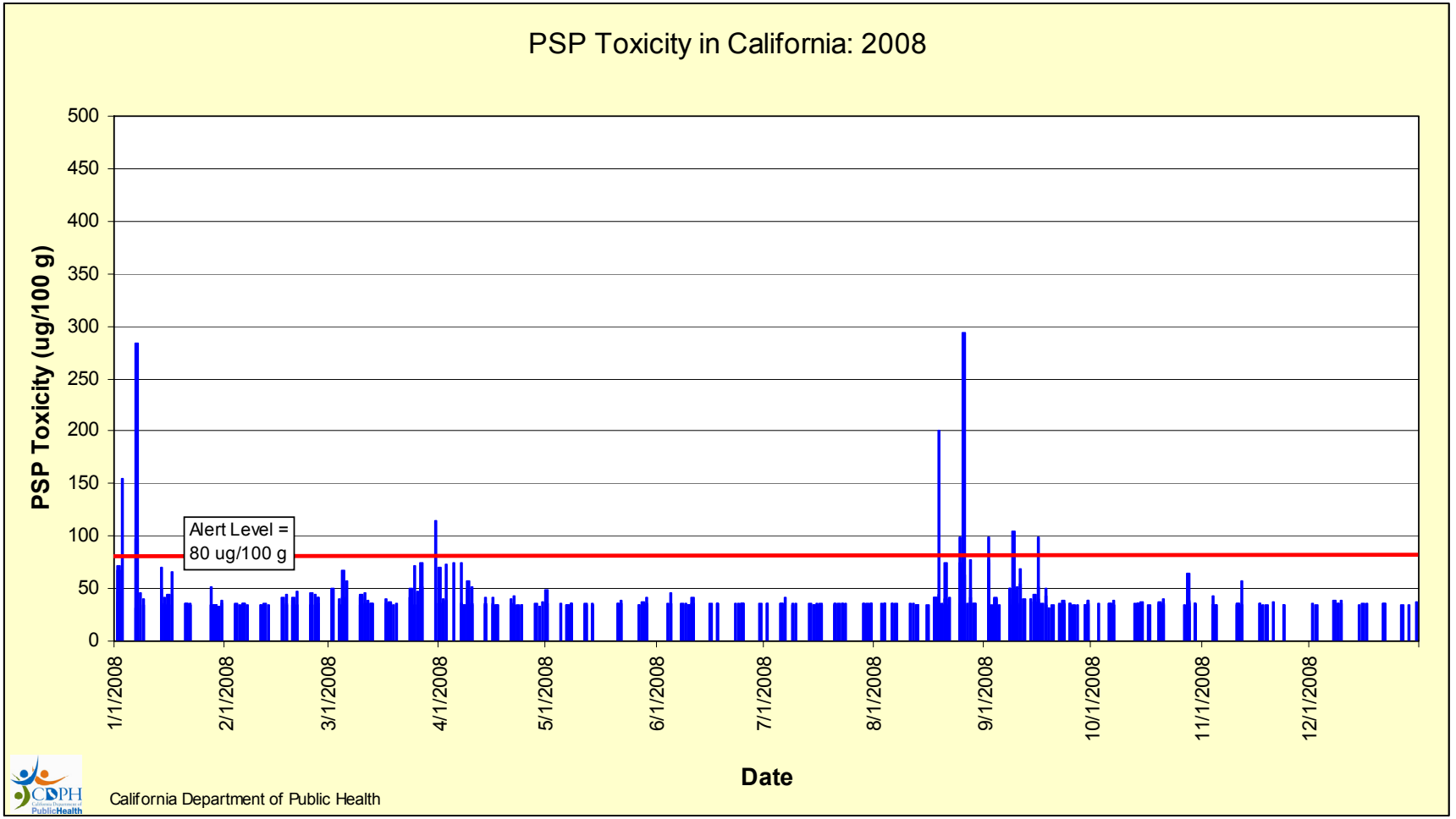


Figure 4. Temporal distribution and percent composition of *Alexandrium spp*. during 2008.

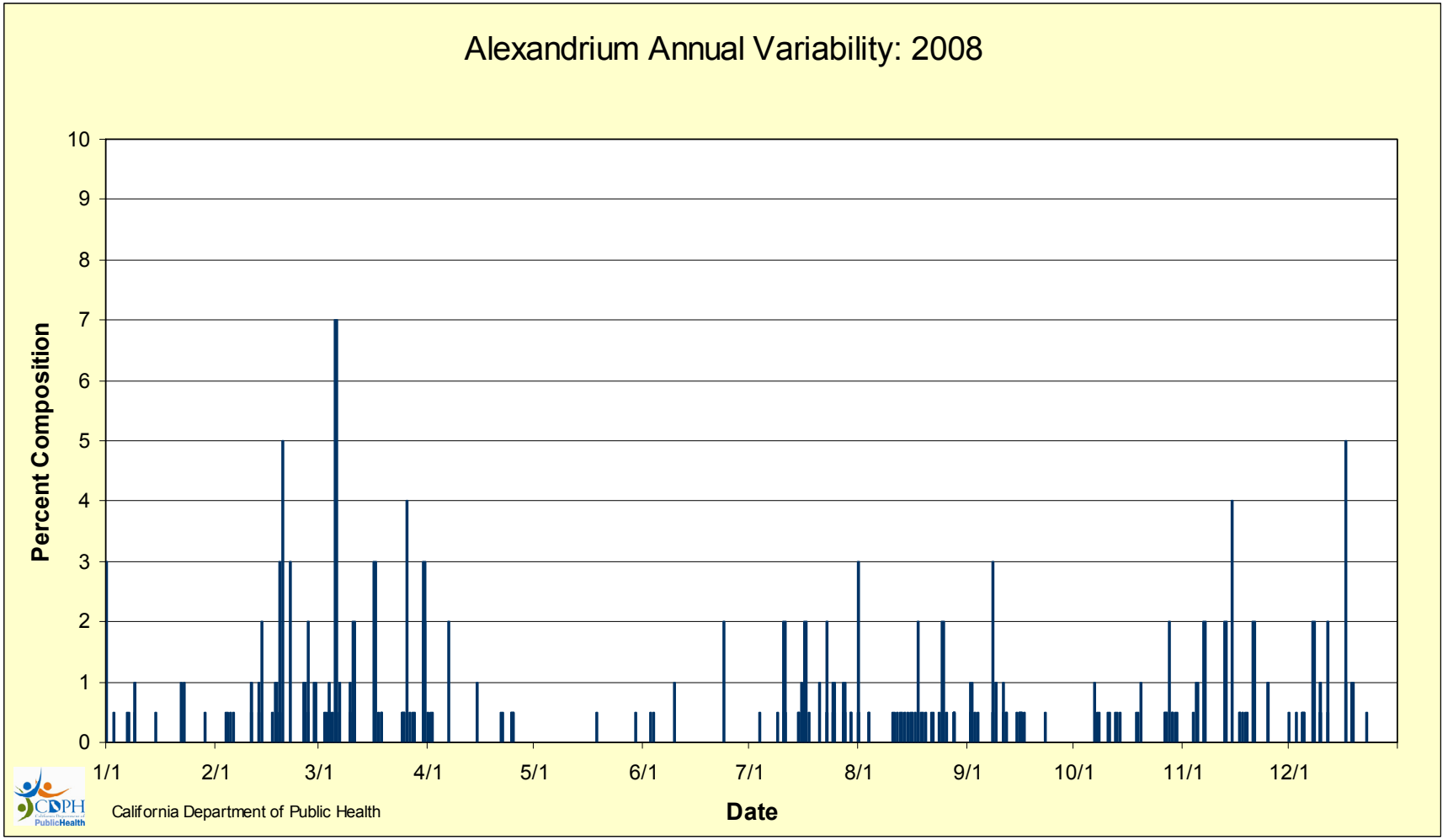


Figure 5. Domoic acid concentration and temporal distribution in California during 2008.

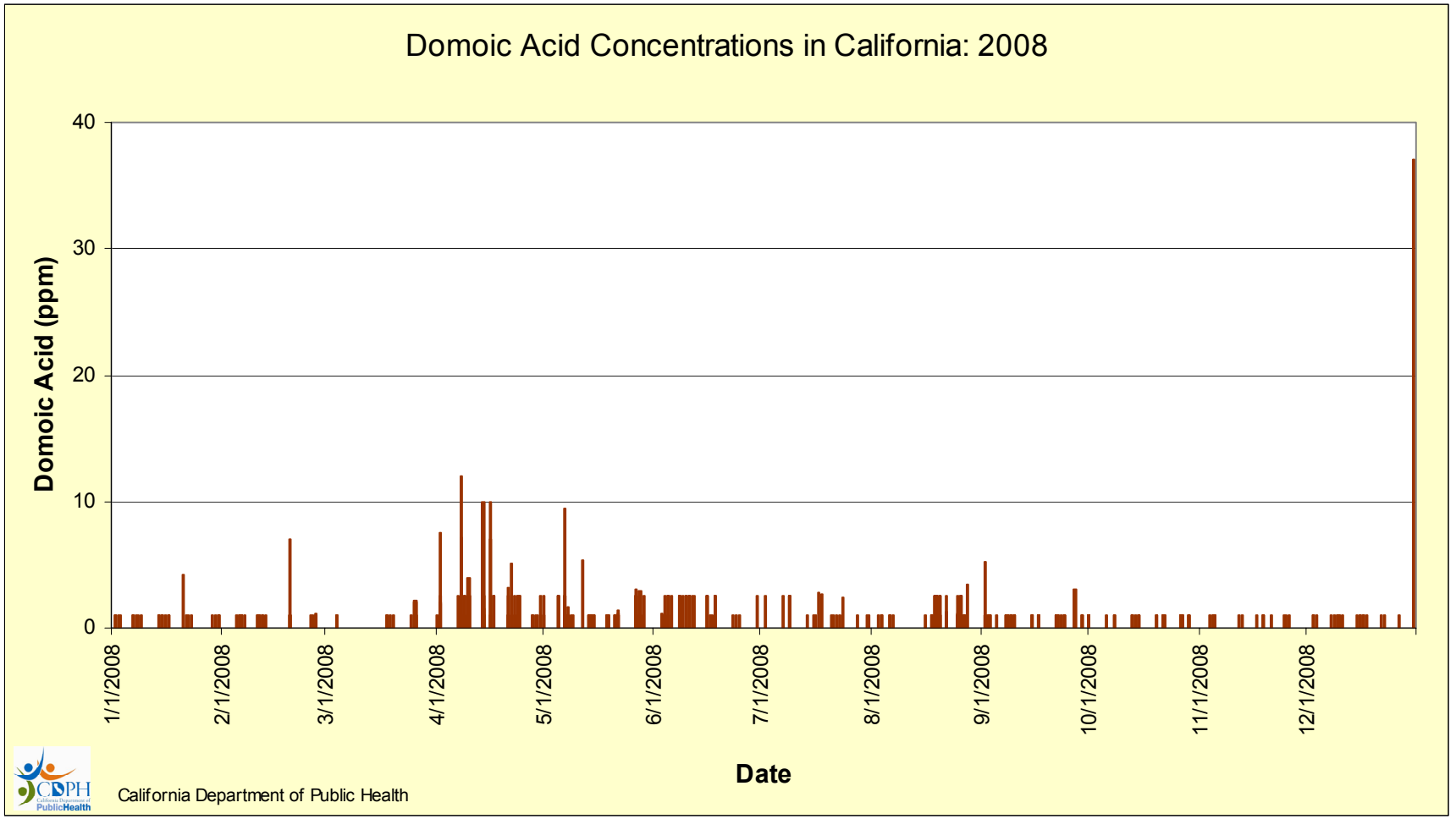


Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia spp*. during 2008.

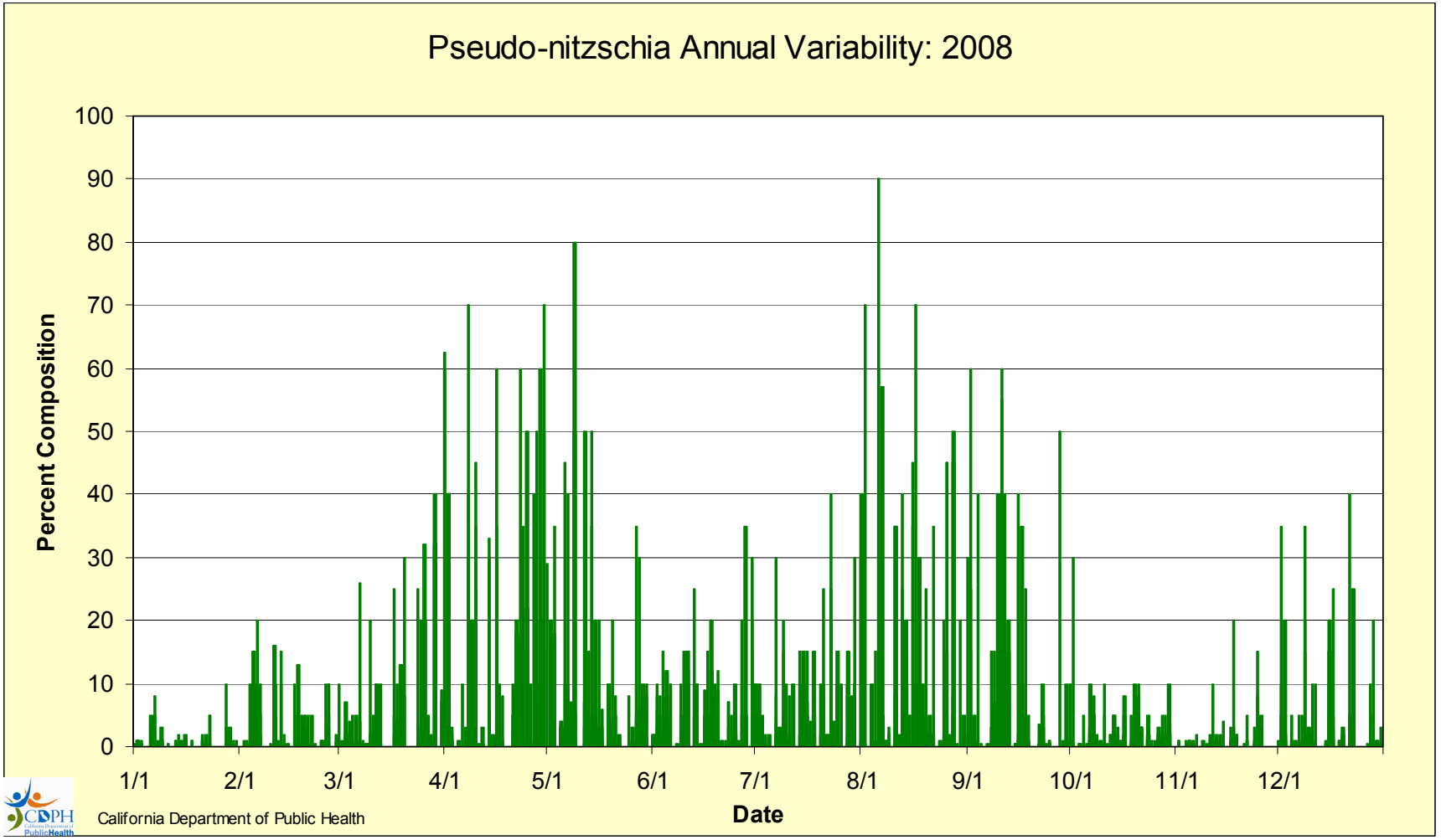


Figure 7. Temporal distribution and relative abundance index (RAI) of *Pseudo-nitzschia spp*. during 2008.