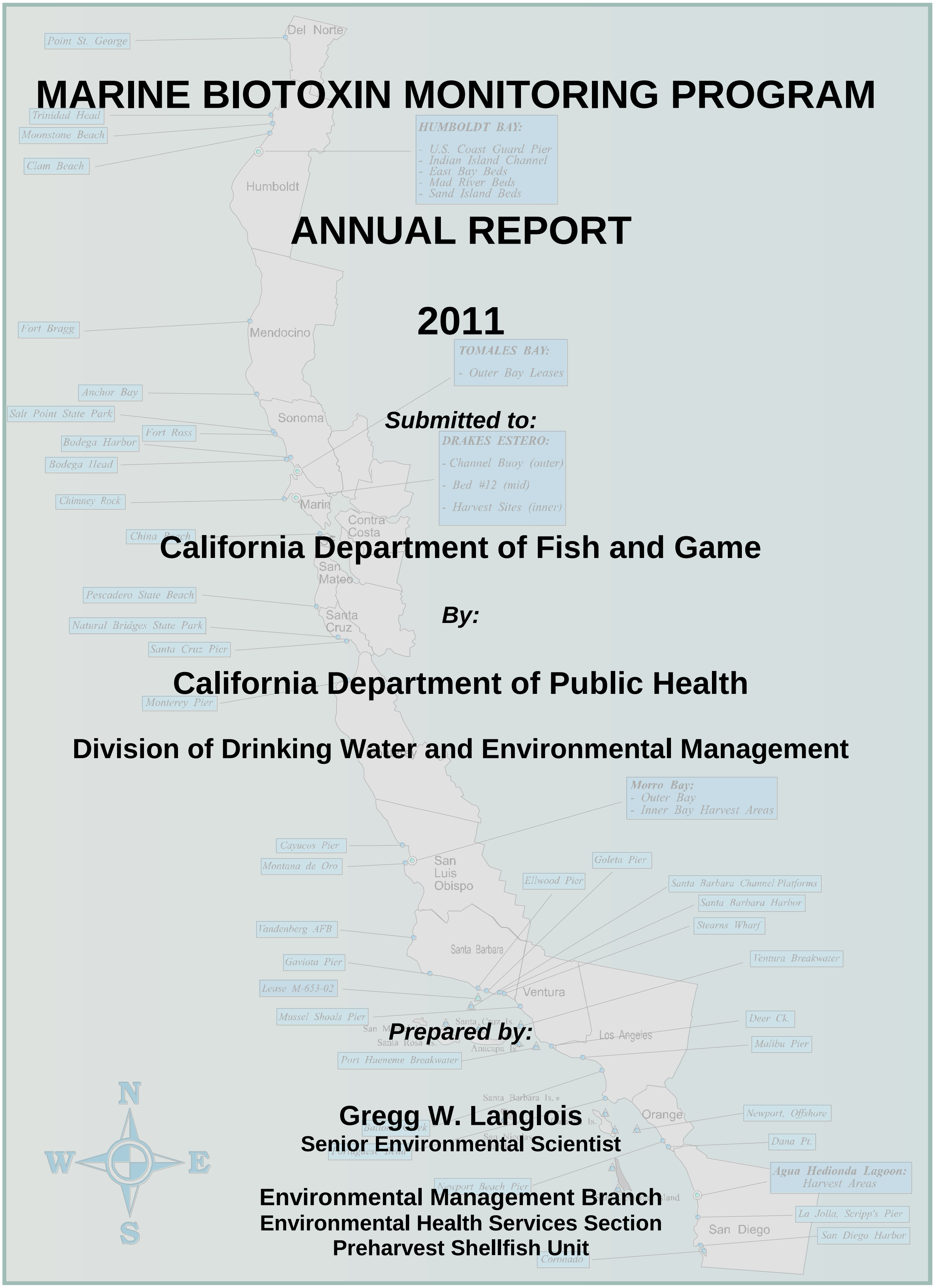

MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2011

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 Unit

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 provides background information on the sampling elements of the program for shellfish toxins and phytoplankton and summarizes the monitoring results for the PSP toxins, domoic acid, and toxigenic phytoplankton for the past year. A summary of quarantine and health advisory activities is also provided.

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.

2011 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 79 different sites along the coast of California in 2011 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1086 shellfish samples collected statewide for PSP toxin assay during 2011. The greatest number of samples (345) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 98 percent of the samples collected in this county.

The majority of these (216) were contributed by Drakes Bay Oyster Company in Drakes Estero, which samples four stations at least weekly. 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 72 percent of all samples collected in 2011, followed by various state agencies (including several universities) and coastal county health departments (12 percent and 8 percent, respectively; Table 2). Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2011. The diversity of participants is a valuable component of the monitoring program (Table 3). As mentioned above, routine sampling along 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 2011 consisted of mussels (70 percent), followed by pacific oysters (29 percent; Table 4). 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 than 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 587 shellfish samples analyzed for domoic acid during 2011 compared to 528 samples analyzed the previous year (Table 5). Samples from 54 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 (236) and San Luis Obispo County (131).

Phytoplankton

There were 1650 phytoplankton samples collected during 2011 by our volunteer-based monitoring effort. These samples were collected at 122 sampling sites representing all coastal counties (Figures 1c and 1d). The greatest numbers of samples were collected in Marin (274), San Luis Obispo (230), and Santa Barbara (198) counties (Table 6). Samples were collected along all coastal counties by 79 different volunteer groups. Several areas (e.g., commercial shellfish growing areas) had multiple sites that are not individually identified in the figure and some volunteers collect samples in multiple counties.

Of the 1650 phytoplankton samples collected in 2011, 1127 (68 percent) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 111 different sampling sites throughout all of the 15 coastal counties in 2011. The greatest numbers of samples containing toxin-producing species were collected in San Luis Obispo (189) and Santa Barbara (175) counties.

2011 RESULTS

The following is a brief summary of general trends in the distribution and relative abundance of toxic phytoplankton and the associated distribution and magnitude of marine biotoxins in shellfish. More detail can be found in the monthly reports produced by the CDPH Marine Biotoxin Program. The monthly reports contain detailed maps that illustrate the weekly domoic acid and PSP toxin concentrations, the distribution and relative abundance of *Alexandrium* and *Pseudo-nitzschia*, and lists of program participants. These reports are available at the following Internet site:

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

Paralytic Shellfish Poisoning Toxicity and *Alexandrium* Observations

The magnitude of PSP toxicity was slightly higher in 2011 compared to 2010 (Figure 2) and the geographic distribution was greater. There were persistent low levels of PSP toxins at the beginning of the year, with a cessation of activity between late April and late July. An extended period of PSP activity occurred from late July through the end of the year (Figure 3). Measurable concentrations of PSP toxins were found in 104 shellfish samples from the following coastal counties: Del Norte, Humboldt, Marin, San Mateo, Santa Cruz, Monterey, Santa Barbara, Los Angeles, Orange, and San Diego. Concentrations of PSP toxins greater than or equal to the alert level (80 µg/100 g of tissue) were detected in eight samples from the following counties: Humboldt, Marin, and Los Angeles.

Low numbers of *Alexandrium* were observed at sites representing each coastal County. This dinoflagellate occurred at multiple sites along the California coast during all months of the year (Figure 4). There was a higher frequency of occurrence between January and April and again between August and December. The greatest relative abundances occurred in November and December, but these were infrequent and short-lived. The majority of *Alexandrium* observations between January and July occurred at sites in southern California. By August there was a shift in *Alexandrium* observations predominantly to central and northern California counties (San Luis Obispo to Del Norte).

The geographic distribution of PSP toxins in shellfish during 2011 was similar to that in 2010 and paralleled the pattern of occurrence in *Alexandrium*. Low levels of PSP toxins were detected at multiple southern California counties in January and March 2011, with occasional positive samples also in April and July (Table 7). A mussel sample collected on March 17 at Ballona Creek by the Los Angeles Health Department contained 220 µg/100 g of PSP toxins, declining to 57 µg/100 g by March 28. There were no positive samples during this period in northern California. A period of extended PSP toxicity in central and northern California began in August and continued throughout the remainder of the year. Toxin concentrations remained low at most sampling sites, with the exception of a notable increase at our sentinel mussel station in outer Humboldt Bay in September. The concentration of PSP toxins reached 126 µg/100 g by September 26 and declined rapidly in subsequent samples. A second increase in toxicity in Humboldt Bay shellfish occurred in late October, reaching 255 µg/100 g at the outer bay sentinel mussel station and 187 µg/100 g in sentinel mussels farther inside the bay (Indian Island) by November 1. PSP toxin concentrations declined below the alert level by November 7, where they remained throughout December. A pattern of persistent PSP toxicity also occurred in Drakes Estero (Marin County) beginning in mid-November. Low concentrations of these toxins were detected in sentinel mussels on November 14 and persisted throughout the remainder of the year. By December 20 the toxin levels had increased to 78 µg/100 g at the sentinel buoy mussel station in the outer Estero, reaching 108 µg/100 g by December 27. In addition, sentinel mussels farther inside the Estero (Bed #12) reached 80 µg/100 g by this date. Samples collected on December 31 indicated a decline in toxicity in the outer Estero sentinel mussel station but a continued increase in sentinel mussels from Bed #12 (112 µg/100 g).

The timing of PSP toxin distribution along the coast in 2011 was somewhat the opposite of what was observed in 2010. During 2010 toxins were first detected primarily in Humboldt County between March and July. Subsequent PSP toxicity was detected in Santa Barbara and Ventura counties between August and October.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

The geographic distribution and magnitude of domoic acid toxicity in 2011 was less than observed in 2010. The temporal distribution of domoic acid was somewhat the reverse of the previous year, with a strong spring event and subsequent second event during the summer months (Figure 5). This is in contrast to the two distinct events in 2010 that occurred in the summer and fall. Measurable concentrations of domoic acid were found in 210 samples during 2011, compared to 149 samples during 2010 and 58 samples in 2009. Domoic acid was detected in samples from the following coastal counties: Humboldt, Sonoma, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Ventura, and Los Angeles. Concentrations of domoic acid above the alert level (20 µg per gram of shellfish meat, or 20 parts per million (ppm)) were detected in 73 samples from the following four counties: Santa Cruz, San Luis Obispo, Santa Barbara, and Ventura. Domoic acid concentrations exceeded the alert level during every month of 2011 except May and September.

Pseudo-nitzschia was observed at sites representing all coastal counties, including sites inside San Francisco Bay, during 2011. The greatest relative abundances were observed along the southern California coast, particularly at sites in San Luis Obispo

County. The estimated percent composition of this diatom exceeded 90 percent at sites along each coastal County between Marin and Los Angeles, with the exception of San Mateo. The percent composition data for *Pseudo-nitzschia* can be misleading, as it does not account for varying cell densities or sampling effort. To adjust for the importance of cell mass, as well as sampling effort, a Relative Abundance Index (RAI) was formulated[1]. 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), providing some additional insight into the periods and locations of greatest cell numbers. The highest RAI values for *Pseudo-nitzschia* occurred in three distinct intervals during 2011: between late January and early April, between late May and August, and to a lesser extent between mid-October and November.

Domoic acid concentrations reached the alert level (20 ppm) in shellfish from an aquaculture lease offshore of Santa Barbara by January 19, then declined to low levels by the following week. Concentrations of this toxin increased again offshore of Santa Barbara and in Morro Bay (San Luis Obispo County) in mid-February, exceeding the alert level at the former location by February 23. Low levels of toxin persisted in Morro Bay and eventually exceeded the alert level on March 29 (27 ppm). Alert levels of domoic acid were also detected in mussels along the Ventura coast during the first two weeks of March, declining and remaining at low levels through the beginning of June.

Domoic acid levels continued to increase at the Santa Barbara site through March, reaching 127 ppm by March 22. Toxin concentrations declined slightly but remained above the alert level, increasing again to 265 ppm and 387 ppm by April 18 in aquacultured mussels and oysters, respectively. There was a subsequent dramatic decline in domoic acid concentrations at the Santa Barbara aquaculture lease, decreasing below the detection limit by the beginning of May. Low levels were again detected at this site by May 17, beginning a pattern of oscillating toxin concentrations above and below the alert level for the next several months before declining below the detection limit in early September. The maximum domoic acid concentrations detected in mussels and oysters at the Santa Barbara lease during this prolonged event were 46 ppm and 84 ppm, respectively.

Varying levels of domoic acid persisted in spiny lobster viscera from offshore locations through most of 2011. It is difficult to infer patterns of increase and decrease in toxin concentrations in offshore samples due to the difficulty in obtaining frequent samples from a wide range of locations (i.e., the northern and southern chains of Channel Islands). The maximum concentrations of domoic acid detected in lobster viscera were 413 ppm near Santa Cruz Island July 14), 119 ppm near Santa Barbara Island (August 8), 77 ppm near San Nicolas Island (January 29), 51 ppm near Anacapa Island (February 21), 50 ppm near Santa Rosa Island (December 22), and 46 ppm along the

[1] *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*

Ventura County coast (January 28). There appeared to be a general decline in offshore levels of domoic acid by the end of the year.

RED TIDE EVENT: SONOMA COUNTY

During the latter part of August the California Department of Fish and Game (DFG) and the Bodega Marine Lab (BML) reported a red tide along the Sonoma coast and began investigating the beginning of a large-scale mortality event involving abalone and numerous other invertebrates. Phytoplankton samples collected by DFG, BML, and CDPH at sites between Bodega Harbor and Salt Point State Park contained an abundance of the dinoflagellate *Gonyaulax spinifera*. This dinoflagellate was also common at several coastal sites between San Mateo and Marin counties. *G. spinifera* is known to produce a compound called Yessotoxin (YTX) that is not considered a public health threat to shellfish consumers. The U.S. Food and Drug Administration (FDA) does not recommend a control limit for YTX. Nonetheless mussel samples collected by DFG along the Sonoma coast were analyzed by CDPH and FDA laboratories for a variety of toxins. The CDPH laboratories reported that domoic acid and the PSP toxins were not detected in the mussel samples. The FDA laboratory detected a number of lipophilic (fat soluble) toxins at trace levels that did not represent a public health concern. No confirmed human health impacts were reported from this massive red tide event. DFG and BML are conducting investigations into the impact of this event on natural resources and on possible causes.

As the bloom of *G. spinifera* began to subside along the Sonoma coast, there was a corresponding increase in diatoms. *Pseudo-nitzschia spp.* began increasing at the Bodega Harbor USCG sentinel station by August 30 and the population peaked by September 8 at this site. As this diatom continued to decline there was an increase in the nontoxic dinoflagellate *Ceratium divaricatum*, creating a second red tide event (Figure 8). This dinoflagellate was common to abundant between San Mateo and Sonoma counties by the end of the month. Although *C. divaricatum* dominated the nearshore phytoplankton assemblage, the diatom *Thalassiothrix* was observed in high numbers offshore throughout this range in samples collected by the Applied California Current Ecosystem Studies partnership (ACCESS; www.accessoceans.org).

C. divaricatum remained dominant along much of the northern California coast through October, expanding its northern range to include Mendocino and southern Humboldt counties. The highest relative abundances of *C. divaricatum* were observed at the Pt. Arena Pier (October 3, declining by October 19) and the Bodega Harbor sentinel station (October 28). High relative abundances of this dinoflagellate were also detected inside Drakes Estero and San Francisco Bay. By the beginning of December *C. divaricatum* was rare at Bodega Harbor and diatoms, particularly *Pseudo-nitzschia spp.*, were common.

2011 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

CDPH issued the annual quarantine on the sport-harvesting of mussels on March 29, one month earlier than the usual May 1 start date. The early start to the annual mussel quarantine was the result of increasing levels of the PSP toxins and domoic acid in a number of different locations. 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 mussel quarantine ended on schedule at midnight October 31.

The health advisory issued on October 16, 2010 remained in place throughout 2011. This advisory warned consumers not to eat sport-harvested shellfish or the internal organs of crustaceans and small finfish from the Channel Islands. Elevated levels of domoic acid were first detected in the viscera of lobster in this region and subsequently in rock crab viscera. This toxin was not detected in meat samples from lobster or crab. DFG issued a separate press release on October 29, 2010 warning all consumers to eat only the tail meat of California spiny lobster and only the meat of crab until further notice. DFG further advised that all internal organs, including the roe, should be discarded.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2011.

REFERENCES

California Department of Health Services Marine Biotoxin Monitoring Program, 1991. “Shellfish biotoxin monitoring program annual report, 1991”, 50 pp.

California Department of Public Health, Marine Biotoxin Monitoring Program Monthly Reports, 2011.

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 2011 for PSP assay.

COUNTY	# SAMPLES
Del Norte	10
Humboldt	126
Mendocino	5
Sonoma	10
Marin	345
San Francisco	11
San Mateo	14
Santa Cruz	52
Monterey	2
San Luis Obispo	173
Santa Barbara	165
Ventura	33
Los Angeles	34
Orange	5
San Diego	101
TOTAL	**1086**

Table 2. Number of shellfish samples collected by program participants, per coastal County, in 2011 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	10	--	--	--	10
Humboldt	117	8	1	--	--	126
Mendocino	--	4	--	--	1	5
Sonoma	--	--	10	--	--	10
Marin	337	--	8	--	--	345
San Francisco	--	11	--	--	--	11
San Mateo	--	14	--	--	--	14
Santa Cruz	--	1	51	--	--	52
Monterey	--	--	--	--	2	2
San Luis Obispo	167	--	3	--	3	173
Santa Barbara	106	--	54	5	--	165
Ventura	--	19	1	--	13	33
Los Angeles	--	20	1	--	13	34
Orange	--	5	--	--	--	5
San Diego	52	--	6	41	2	101
TOTAL =	**779**	**92**	**135**	**46**	**34**	**1086**

Table 3. Program participants by county that submitted shellfish samples in 2011 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
Humboldt	Coast Seafoods Company
	Humboldt County Environmental Health Department
	California Department of Fish and Game
	Humboldt Bay Oyster Company
	North Bay Shellfish Company
	Humboldt State University Marine Lab
	CDPH Volunteer
Mendocino	CDPH Volunteer
	Mendocino County Environmental Health Department
Sonoma	CDPH Marine Biotoxin Monitoring Program
	California Department of Fish and Game
Marin	Cove Mussel Company
	Drakes Bay Oyster Company
	CDPH Marine Biotoxin Monitoring Program
	Hog Island Oyster Company
	Marin Oyster Company
San Francisco	San Francisco County Health Department
San Mateo	San Mateo County Environmental Health Department
Santa Cruz	Santa Cruz County Environmental Health Department
	University of California Santa Cruz
Monterey	Monterey Abalone Company
San Luis Obispo	Grassy Bar Oyster Company
	Morro Bay Oyster Company LLC
	CDPH Volunteer
	Cal Poly
	CDPH Marine Biotoxin Monitoring Program
Santa Barbara	Santa Barbara Mariculture Company
	University of California Santa Barbara
	Sea Grant Extension, UC Santa Barbara
	Vandenberg Air Force Base, Environmental Health Services
	CDPH Volunteer

	California Department of Fish and Game
	Wild Planet Foods
	CDPH Marine Biotoxin Monitoring Program
Ventura	Ventura County Environmental Health Department
	CDPH Volunteer
	California Department of Fish and Game
	University of California Santa Barbara
	Coastal Marine Bioloabs
Los Angeles	Los Angeles County Health Department
	California Department of Fish and Game
	CDPH Volunteer
Orange	Orange County Health Care Agency
San Diego	Carlsbad Aquafarm, Inc.
	U.S. Navy Marine Mammal Program
	CDPH Volunteer
	Scripps Institute of Oceanography

Table 4. Number and species of samples collected in 2011 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[2]:	
Wild	73
Sentinel	85
Cultured	140
Total Bay Mussels	***298***
Sea Mussels[3]:	
Sentinel	271
Wild	188
Total Sea Mussels	***459***
Total Mussels	**757**
Pacific Oysters[4]	
Cultured	319
Total Oysters	**319**
Other[5]	**10**
TOTAL	**1086**

[2] *Mytilus galloprovincialis or M. trussulus*
[3] *Mytilus californianus*
[4] *Crassostrea gigas*
[5] *Pismo clam, Spiny Lobster, Rock Crab*

Table 5. Total number of samples analyzed for domoic acid, per coastal county, in 2011.

COUNTY	# SAMPLES
Del Norte	1
Humboldt	11
Mendocino	0
Sonoma	17
Marin	2
San Francisco	0
San Mateo	0
Santa Cruz	46
Monterey	2
San Luis Obispo	131
Santa Barbara	236
Ventura	41
Los Angeles	34
Orange	2
San Diego	64
TOTAL	**587**

Table 6. Total number of phytoplankton samples collected per coastal county in 2011.

COUNTY	# SAMPLES
Del Norte	27
Humboldt	58
Mendocino	19
Sonoma	29
Marin	274
Contra Costa	5
Alameda	11
San Francisco	107
San Mateo	89
Santa Cruz	105
Monterey	69
San Luis Obispo	230
Santa Barbara	198
Ventura	82
Los Angeles	129
Orange	77
San Diego	137
TOTAL	**1509**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2011.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
01/12/11	Santa Barbara	Sea Mussel, wild	Goleta Pier	35
01/18/11	Los Angeles	Sea Mussel, wild	Portuguese Bend	38
01/19/11	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	35
01/19/11	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	37
01/26/11	Santa Barbara	Sea Mussel, wild	Goleta Pier	36
01/28/11	Ventura	Lobster, Spiny, viscera	Ventura, Pt. Hueneme E. Jetty	38
FEBRUARY				
MARCH				
03/16/11	Los Angeles	Sea Mussel, wild	Portuguese Bend	43
03/17/11	Los Angeles	Bay Mussel, wild	Ballona Creek	**220**
03/22/11	Orange	Sea Mussel, wild	Newport Beach Pier	44
03/22/11	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	37
03/28/11	Los Angeles	Sea Mussel, wild	Malibu Pier	41
03/28/11	Los Angeles	Bay Mussel, wild	Ballona Creek	57
03/29/11	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	35
03/31/11	Orange	Sea Mussel, wild	Newport Beach Pier	46
APRIL				
04/18/11	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02-O	38
04/18/11	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02-M	36
MAY				
JUNE				
JULY				
07/20/11	Los Angeles	Sea Mussel, wild	Portuguese Bend	48
AUGUST				
08/10/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	41
08/17/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	42
08/29/11	Del Norte	Sea Mussel, wild	Point St. George	42

08/29/11	Monterey	Sea Mussel, wild	Monterey Bay, Commercial Wharf	36
SEPTEMBER				
09/06/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	69
09/07/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	44
09/13/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	78
09/14/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
09/19/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
09/19/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	**126**
09/21/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	39
09/21/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	37
09/26/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	60
09/26/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	39
09/27/11	Humboldt	Sea Mussel, wild	Trinidad Head	46
09/28/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	45
09/29/11	San Mateo	Sea Mussel, wild	Pescadero State Beach	37
OCTOBER				
10/03/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	45
10/03/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	56
10/05/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	54
10/11/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
10/11/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	36
10/12/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	42
10/18/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	38
10/19/11	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	34
10/25/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	41
10/25/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	68
10/25/11	Humboldt	Sea Mussel, wild	Trinidad Head	45
10/26/11	Del Norte	Sea Mussel, wild	Point St. George	40
NOVEMBER				
11/01/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	**187**
11/01/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	**255**
11/03/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	**143**

11/03/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	75
11/03/11	Humboldt	Pacific Oyster, cultured	Humboldt Bay, Sand Island N.	40
11/03/11	Humboldt	Pacific Oyster, cultured	Humboldt Bay, Mad River 3-1	52
11/07/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	68
11/07/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	59
11/07/11	Humboldt	Bay Mussel, cultured	Humboldt Bay, WQ #T2a	37
11/07/11	Humboldt	Pacific Oyster, cultured	Humboldt Bay, WQ #33	36
11/08/11	Humboldt	Sea Mussel, wild	Trinidad Head	38
11/14/11	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	41
11/15/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	38
11/15/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	38
11/15/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	45
11/15/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	61
11/15/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	58
11/15/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	43
11/16/11	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	33
11/16/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	58
11/17/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	51
11/17/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	43
11/17/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	41
11/17/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #15	40
11/21/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	65
11/21/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	41
11/21/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	52
11/21/11	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	38
11/22/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
11/22/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	36
11/23/11	Ventura	Lobster, Spiny, viscera	Ventura Harbor Breakwater	34
11/29/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	35
11/29/11	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	36
11/29/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
11/29/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	35

11/29/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	34
11/29/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	38
DECEMBER				
12/06/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	35
12/07/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	49
12/13/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	42
12/13/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	37
12/14/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	50
12/20/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	43
12/20/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #39	38
12/20/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	78
12/20/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	47
12/21/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	54
12/23/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	69
12/27/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	**108**
12/27/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	**80**
12/27/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #8	44
12/27/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	56
12/30/11	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	60
12/30/11	Ventura	Lobster, Spiny, viscera	Ventura Harbor Breakwater	36
12/31/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	**112**
12/31/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #22	47
12/31/11	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	50
12/31/11	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	57

FIGURES 1 – 7.

Figure 1a. Locations of shellfish sampling stations during 2011 (Del Norte to Monterey counties).

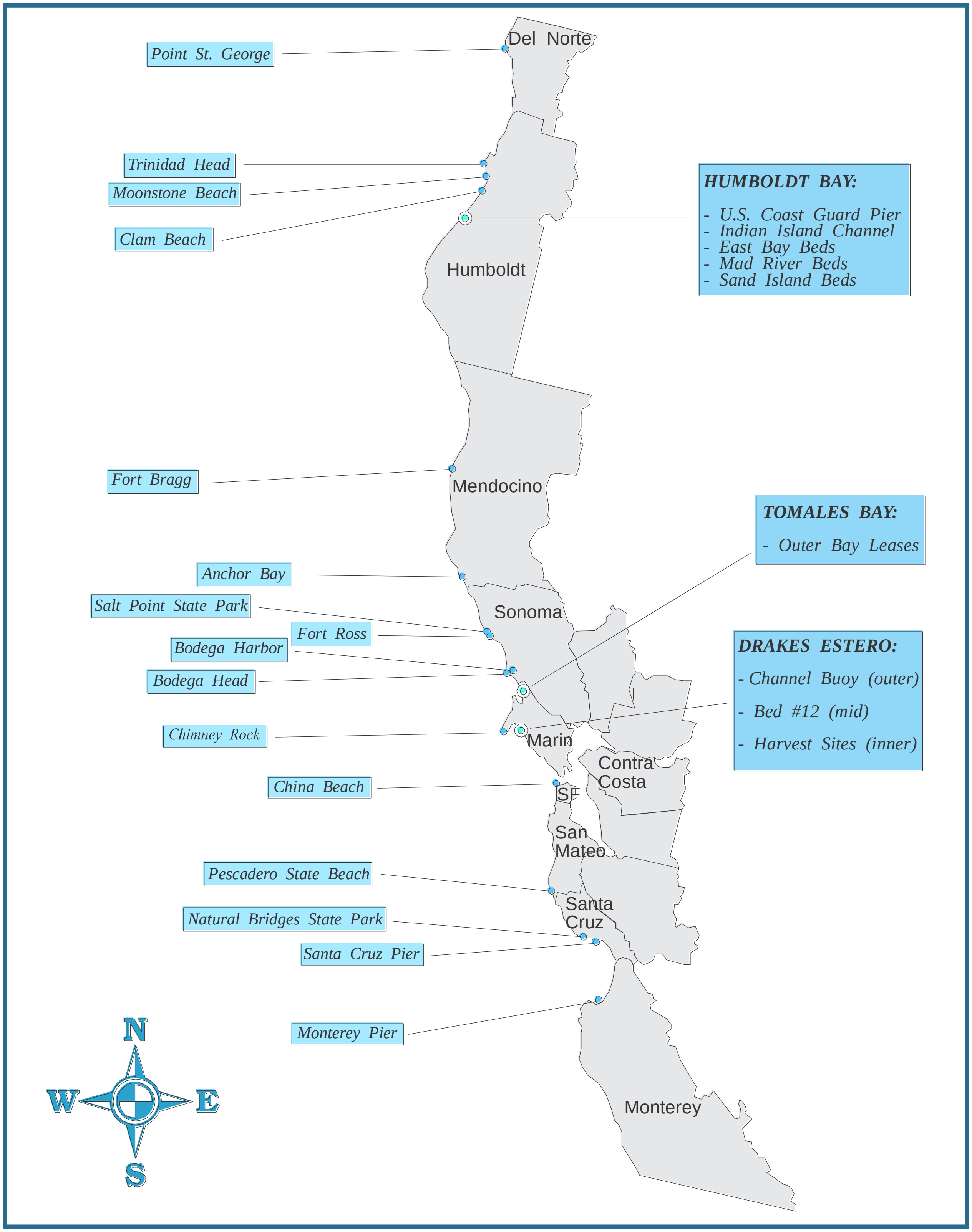

Figure 1b. Locations of shellfish sampling stations during 2011 (San Luis Obispo to San Diego counties).

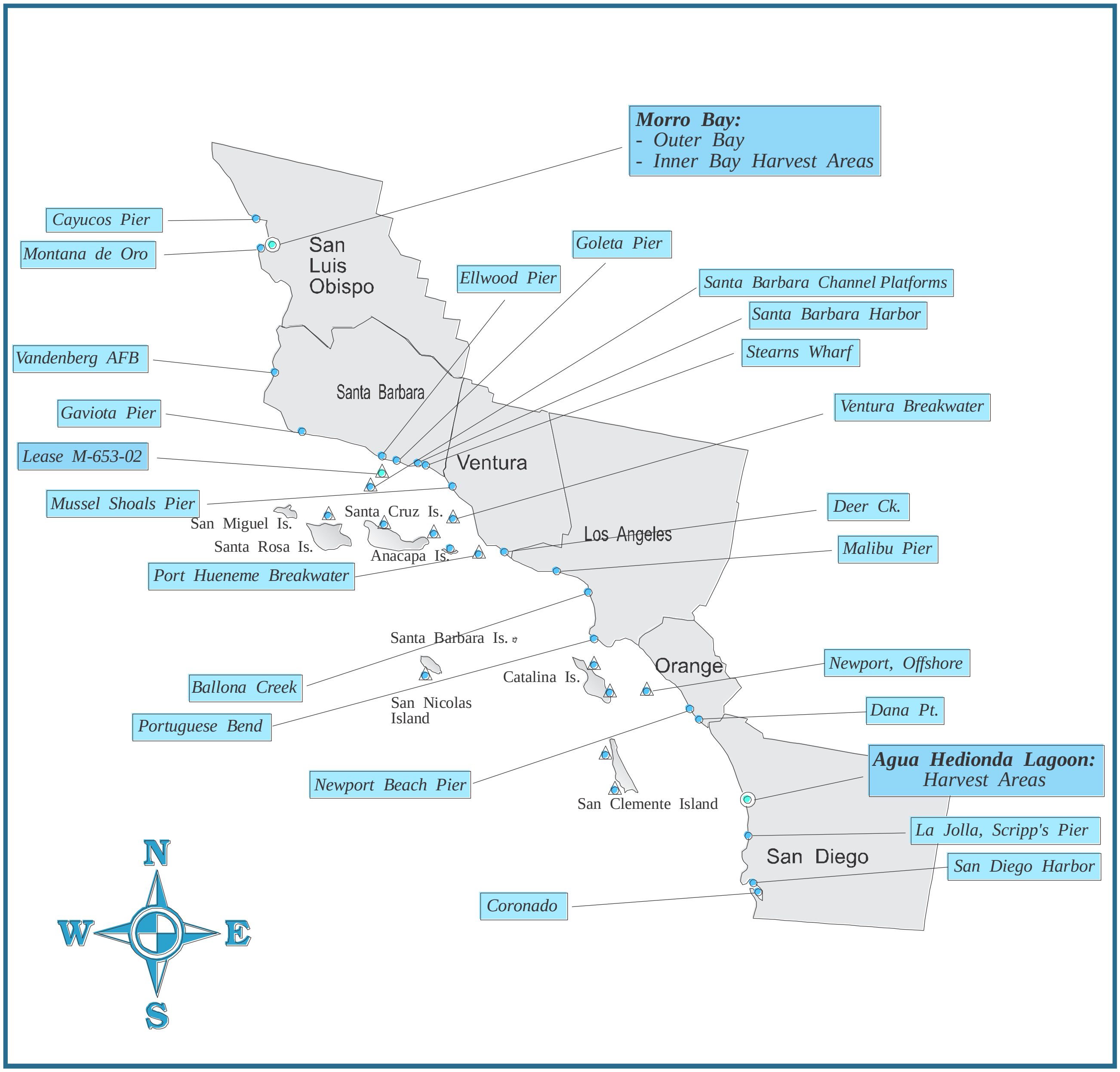

Figure 1c. Locations of phytoplankton sampling stations during 2011 (Del Norte to Monterey counties).

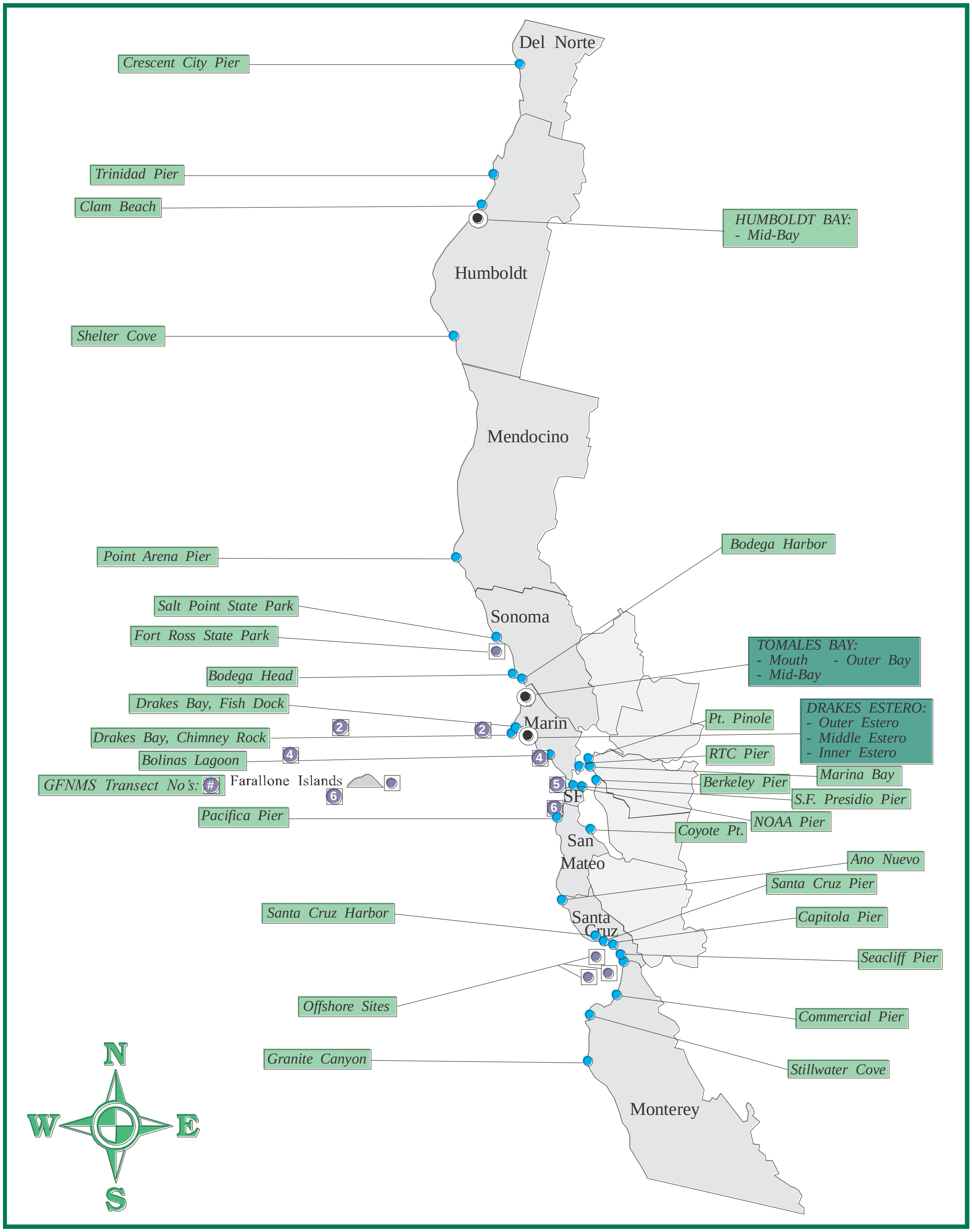

Figure 1d. Locations of phytoplankton sampling stations during 2011 (San Luis Obispo to San Diego counties).

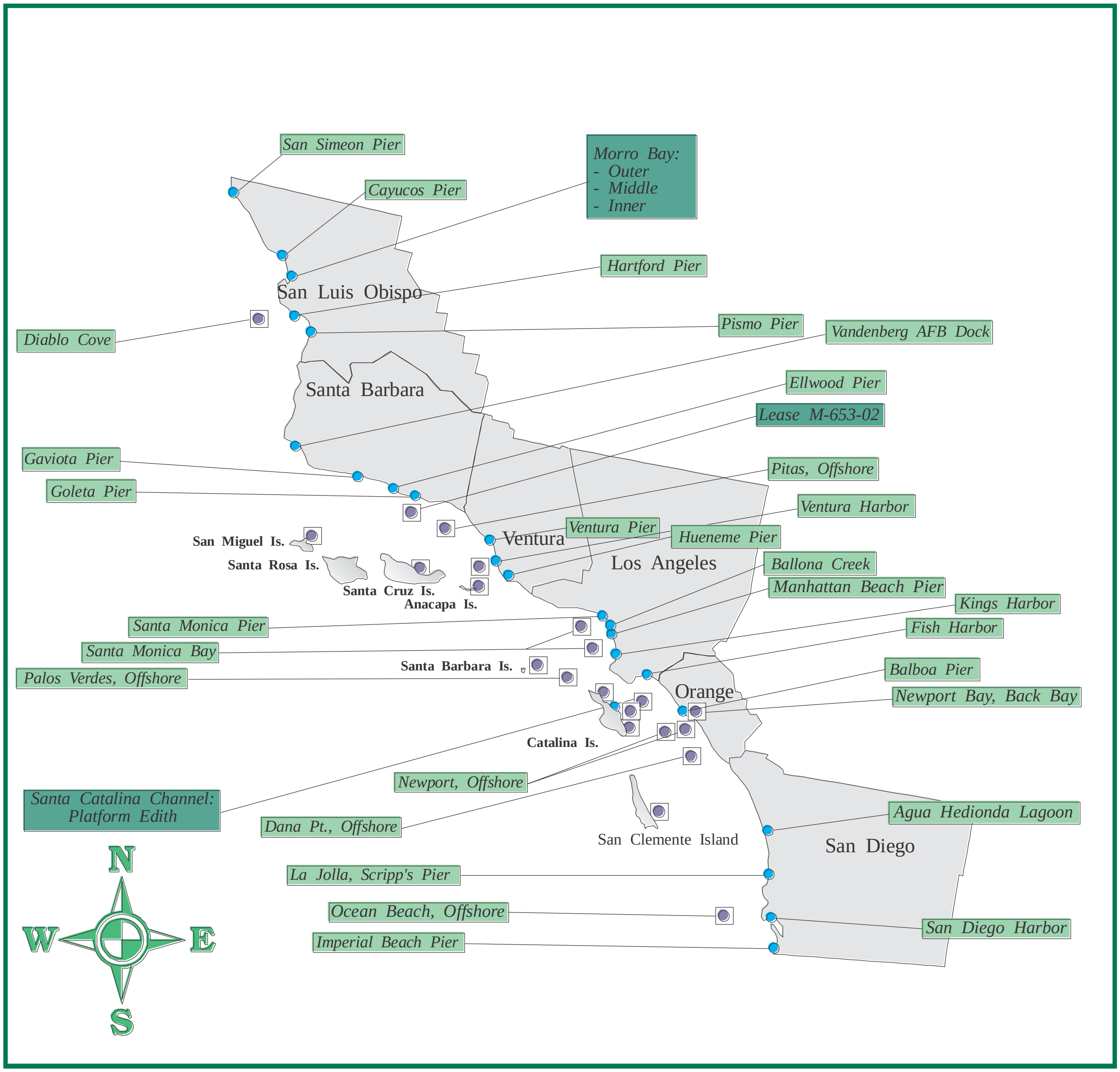

Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2011.

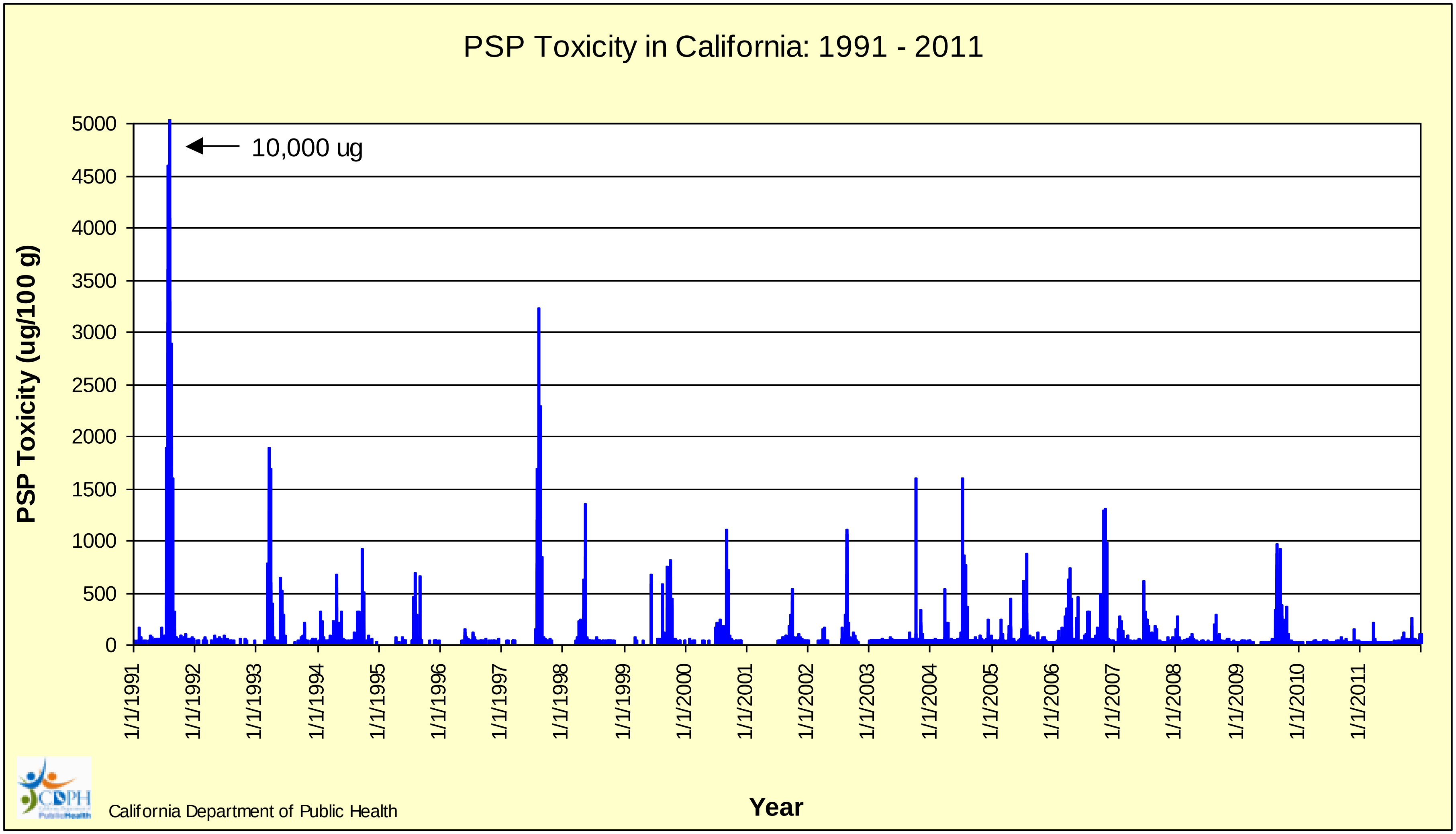

Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2011.

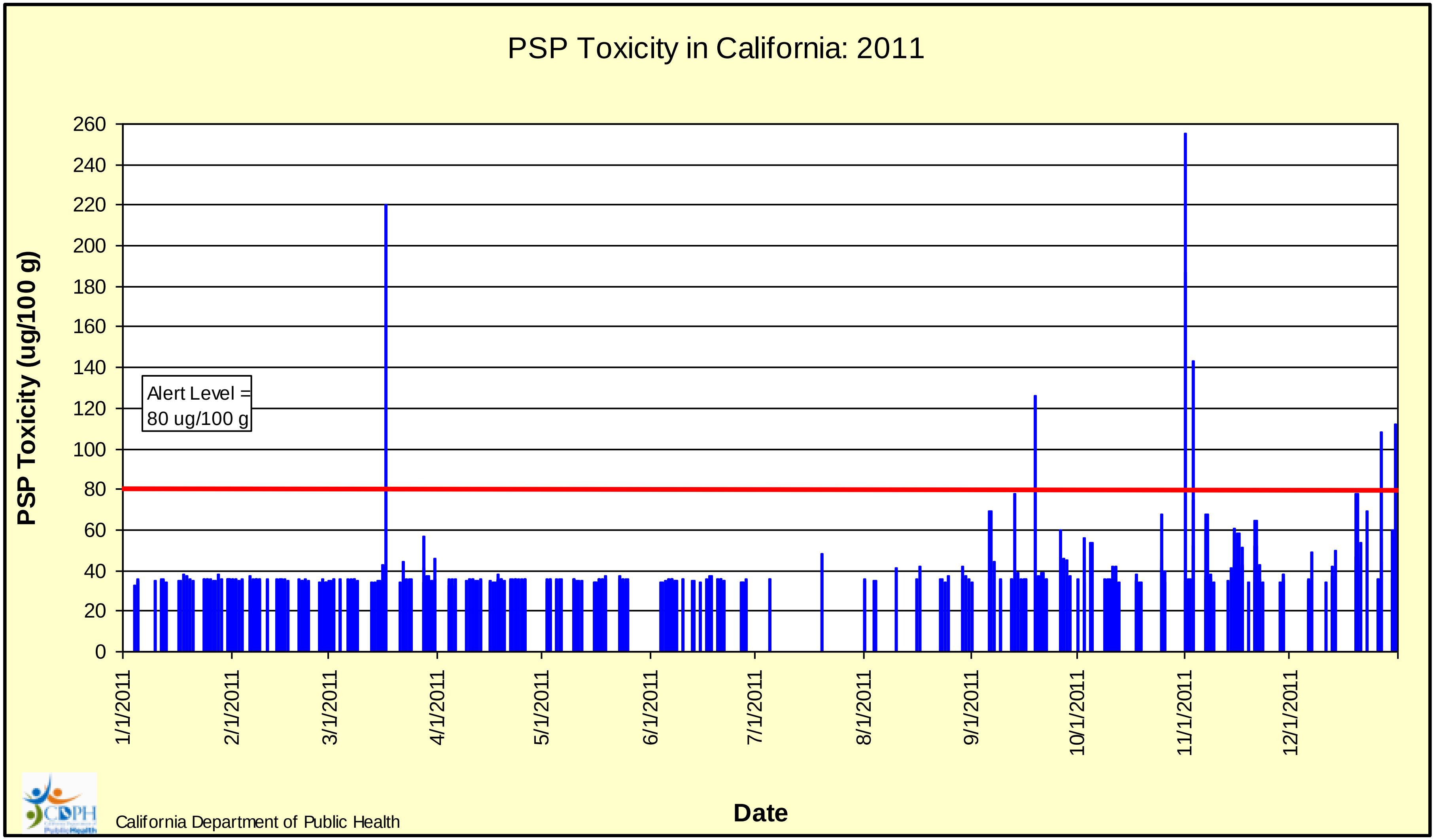

Figure 4. Temporal distribution and percent composition of *Alexandrium spp*. during 2011.

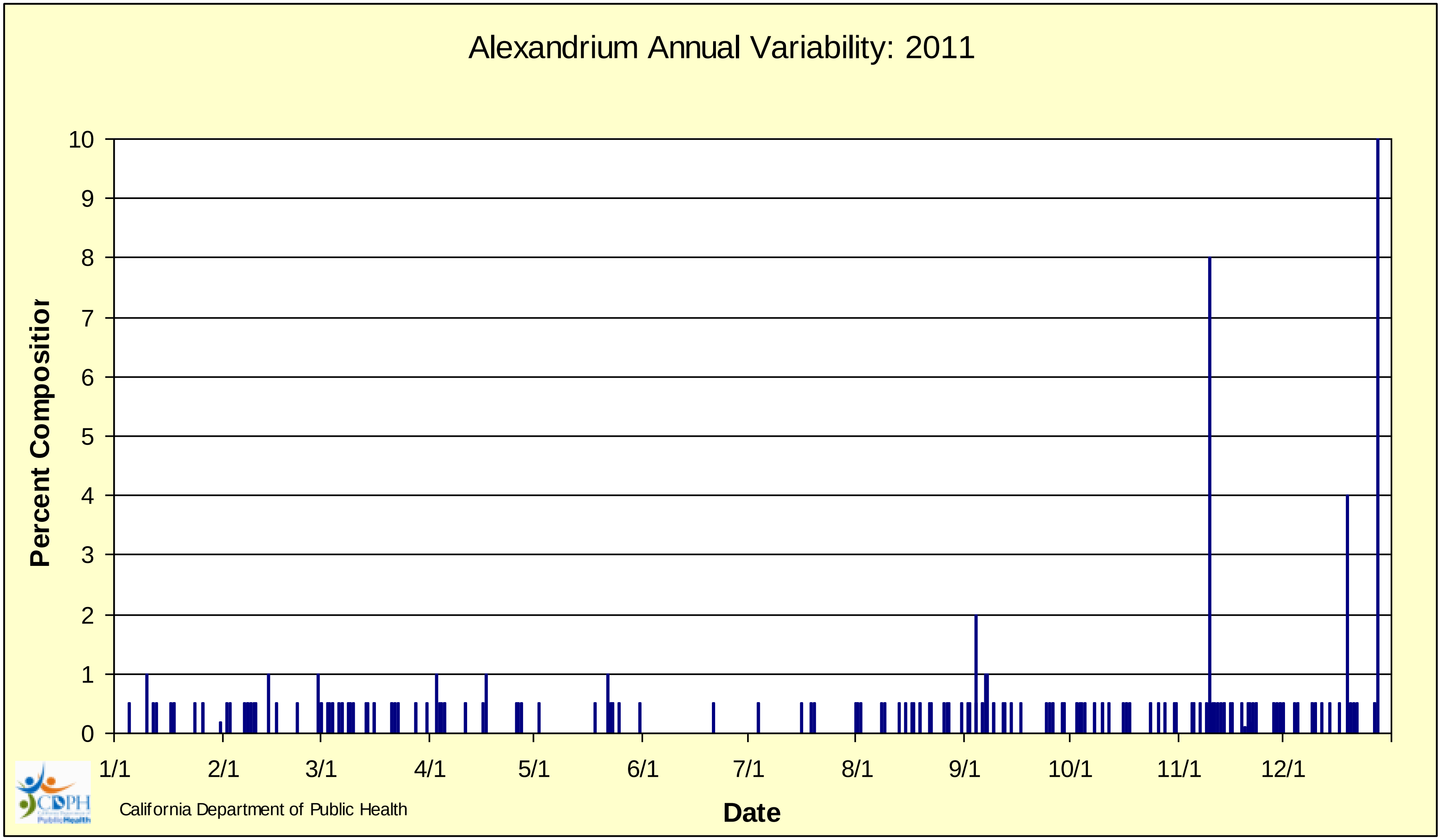

Figure 5. Domoic acid concentration and temporal distribution in California during 2011.

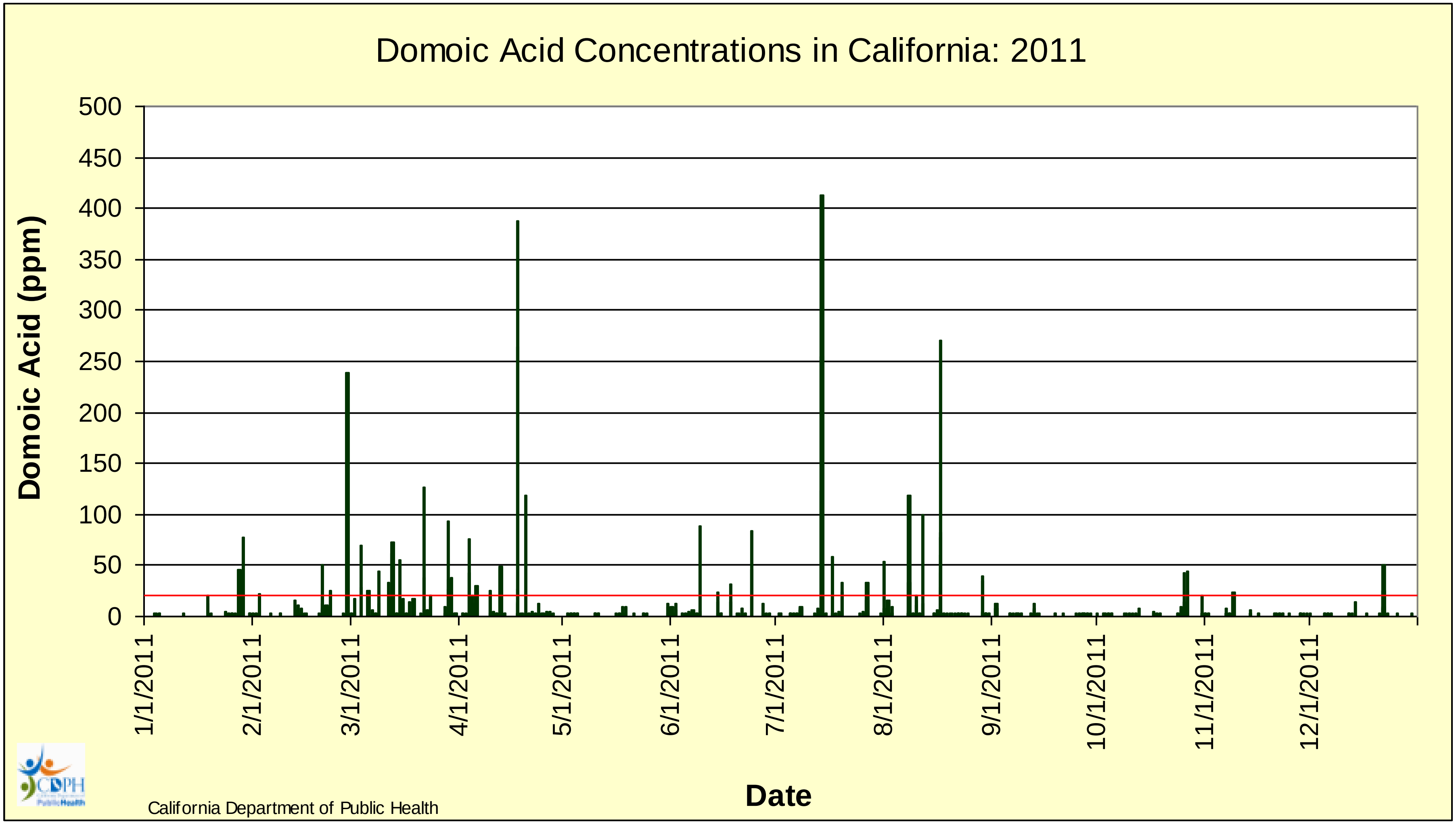

Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia spp*. during 2011.

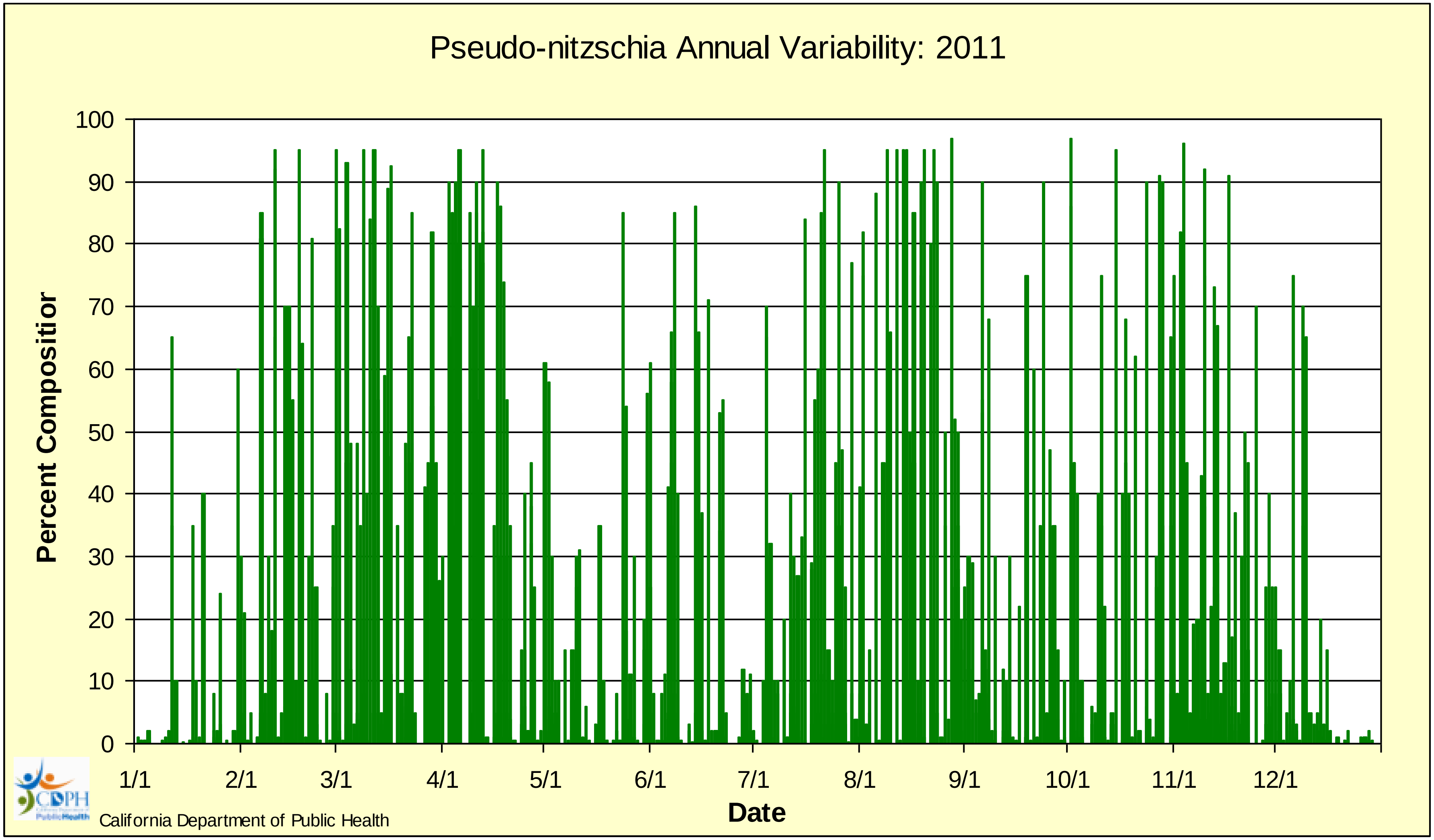

Figure 7. Temporal distribution and relative abundance index (RAI) of *Pseudo-nitzschia spp*. during 2011.

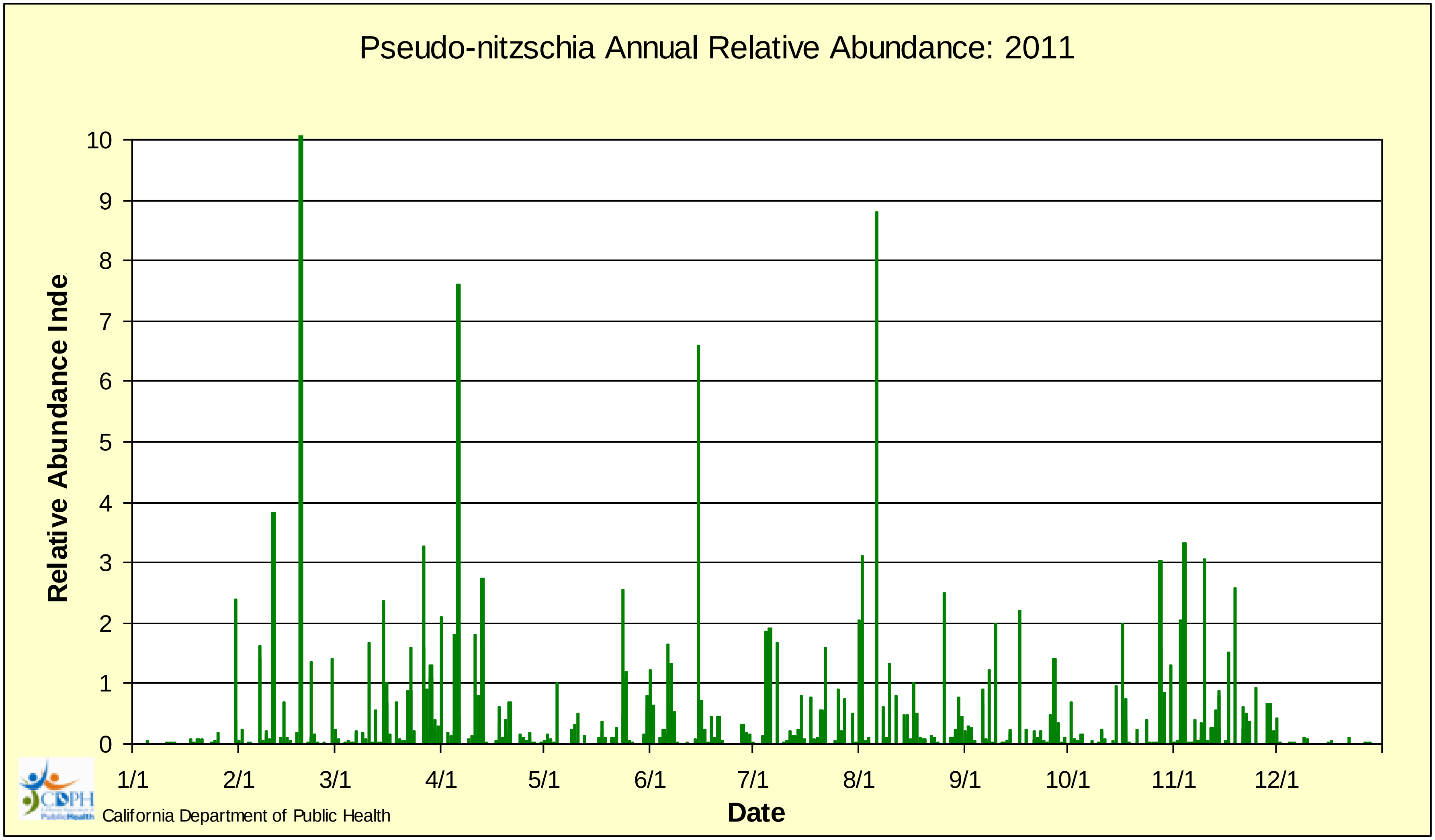

Figure 8. Major taxa observed at the Bodega Harbor USCG sentinel station during the Sonoma coast red tide event.