MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2012

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By:

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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.

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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 20 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 six basic elements: (1) a coastal phytoplankton monitoring program for early detection of toxigenic species that could impact shellfish resources; (2) a coastal shellfish monitoring program that serves to protect recreational harvesters and serves as an early warning for harmful algal blooms (HABs) that could be transported into the bays and estuaries used for commercial shellfish aquaculture; (3) frequent monitoring of commercial shellfish growing areas; (4) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); (5) mandatory reporting of disease cases; (6) public information and education activities. 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 first of its kind in the U.S. 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.

Routine monitoring of the phytoplankton community provides an additional layer of protection because of the ability to detect other toxin-producing species not previously known to be a problem along the California coast. For example, low numbers of the dinoflagellate *Dinophysis spp.* have been observed on many occasions, but not at cell densities indicative of a bloom. The ability to readily identify this species in routine sample observations will allow a rapid response in the event that significant cell numbers occur.

2012 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 92 different sites along the coast of California in 2012 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1137 shellfish samples collected statewide for PSP toxin assay during 2012. The greatest number of samples (407) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 95 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 2012, followed by various state agencies (including several universities) and coastal county health departments (14 percent and 5 percent, respectively; Table 2). Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2012. 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 2012 consisted of mussels (66 percent), followed by pacific oysters (32 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 527 shellfish samples analyzed for domoic acid during 2012 compared to 587 samples analyzed the previous year (Table 5). Samples from 67 different sampling sites were targeted for analysis as a result of observations from the volunteer monitoring network of high numbers of *Pseudo-nitzschia spp.* within the region. The greatest numbers of samples were submitted from Santa Barbara County (139) and San Luis Obispo County (98).

Phytoplankton

There were 1769 phytoplankton samples collected during 2012 by our volunteer-based monitoring effort, the largest number of annual samples ever collected by the program. These samples were collected by 89 samplers at 139 sampling sites representing all coastal counties and two counties bordering San Francisco Bay (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 collect samples in multiple counties. The greatest numbers of samples were collected in Marin (293), San Luis Obispo (236), San Diego (189), Santa Barbara (187), and Los Angeles (144) counties (Table 6).

Of the 1769 phytoplankton samples collected in 2012, 1071 (61 percent) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 119 different sampling sites throughout all of the 15 coastal counties in 2012. The greatest numbers of samples containing toxin-producing species were collected in San Luis Obispo (155), Santa Barbara and San Diego (137), and Marin (121) counties.

2012 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 higher in 2012 compared to 2011 (Figure 2), mostly on the basis of a large fall and winter event (Figure 3). The geographic distribution was also greater in 2012. There was a return to the pattern of PSP toxin distribution being confined to central and northern California sites. The highest levels were detected in mussels from the northern coastal counties of Humboldt and Del Norte. Measurable concentrations of PSP toxins were found in 104 shellfish samples from the following coastal counties: Del Norte, Humboldt, Sonoma, Marin, San Mateo, and Santa Cruz. Concentrations of PSP toxins greater than or equal to the alert level (80 µg/100 g of tissue) were detected in 19 samples from the following counties: Del Norte, Humboldt, and Marin.

Low numbers of *Alexandrium* were observed at sites representing each coastal County during 2012. This dinoflagellate occurred at multiple sites along the California coast during all months of the year except July (Figure 4). The cell numbers of this dinoflagellate were low in all observations. The highest relative abundance of *Alexandrium* was observed in a sample collected near the Farallon Islands on October 23. The greatest frequency of occurrence and highest relative abundances were observed between September and December between Marin and Humboldt counties. Alexandrium was also common throughout this period at Pacifica Pier (San Mateo County). Samples were not available from Del Norte County so information on temporal distribution and relative abundance are not available for that region.

Similar to the beginning of 2011 there were persistent low levels of PSP toxins in January of 2012, briefly exceeding the alert level in sentinel mussels inside Drakes Estero. There was no significant PSP toxicity detected between January 24 and October 2. During the first week of October there was a low level of PSP toxins detected in sentinel mussels from Bodega Harbor (Sonoma County) and Tomales Bay (Marin County). By mid-month mussels from Trinidad Head and the Indian Island sentinel station in Humboldt Bay were found to contain low levels of PSP toxins. Toxicity increased above the alert level at the latter location by October 23 (Table 7). A mussel sample from Wilson Creek (Del Norte County) contained 6394 µg /100 g of the PSP toxins on October 29. This is the highest PSP concentration on record for this County and the highest level detected statewide since 1991. Mussels at this site remained above the alert level through December. Mussels from Humboldt County remained above the alert level through mid-November and contained detectable levels of toxin through December.

As toxin levels declined in these northern counties there was an increase in toxicity at sites in Sonoma and Marin counties. By mid-November the PSP toxin concentration exceeded the alert level at Kehoe Beach and inside Drakes Estero (Marin County). Low levels of toxin were detected in mussels inside Tomales Bay, increasing above the alert level by November 29 then quickly declining to safe levels. PSP toxicity decreased below the alert level in Drakes Estero by the beginning of December but remained detectable throughout the month.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

The geographic distribution and magnitude of domoic acid toxicity in 2012 was less than observed in 2011. The temporal distribution of domoic acid was somewhat different than the prior year, lacking a strong spring event but exhibiting a summer period of toxicity (Figure 5). Measurable concentrations of domoic acid were found in 149 samples during 2012, compared to 210 samples during 2011. Domoic acid was detected in samples from the following coastal counties: Sonoma, Santa Cruz, San Luis Obispo, Santa Barbara, and Ventura. Concentrations of domoic acid above the alert level (20 µg per gram of shellfish meat, or 20 parts per million (ppm)) were detected in 52 samples from the following four counties: Sonoma, Santa Cruz, San Luis Obispo, Santa Barbara, and Ventura. Half of these samples were bivalve shellfish and the other half were comprised mostly of viscera from rock crab and lobster collected around the northern Channel Island chain. A small number of anchovy samples from the Ventura coast were also collected and analyzed. Domoic acid concentrations exceeded the alert level during every month of 2012 except for the period between February and May.

Pseudo-nitzschia was observed at sites representing all coastal counties except Del Norte, during 2012. The latter County was lacking sampling effort throughout the year. The greatest relative abundances were observed along the central and 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 Santa Cruz and Santa Barbara, a significant reduction in range compared to 2011 (Marin to Los Angeles). 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 late May and more significantly near the beginning of July.

Corresponding to the late June increase in *Pseudo-nitzschia*, domoic acid concentrations increased during this period. There was a sudden increase in domoic acid in shellfish from Morro Bay (San Luis Obispo County) at the end of June. Sentinel mussels from outer Morro Bay increased from nondetectable levels of domoic acid on June 19 to above the alert level of 20 ppm by June 25 (31 ppm). Toxin levels increased in oysters farther inside the bay at this time, exceeding the alert level by July 2 (31 ppm). Sentinel mussels collected on this date had increased to 100 ppm of domoic acid. This toxin was also detected in razor clams from Oceano Dunes (97 ppm) on July 5. Low concentrations of domoic acid were detected at Montana de Oro and the Cal Poly Pier in Avila through the end of July.

By July 9 mussels and oysters at an aquaculture lease offshore of Santa Barbara were found to contain low levels of domoic acid (7.2 and 4.6 ppm, respectively). Within two days the toxin levels increased above the alert level, subsequently reaching 84 ppm and 86 ppm by July 16 in mussels and oysters, respectively. The concentration of domoic acid declined well below the alert level at the aquaculture lease by July 20, but increased again to the preceding high concentration levels the following week. By August 6 the toxin levels again declined below the alert level, with mussels and oysters both below the detection limit by August 9. Domoic acid was not detectable in shellfish samples from Ventura County until August 6, when mussels from Deer Creek in the southern part of the county increased to 26 ppm. By August 21 the level had dropped below the detection limit at this site.

During this domoic acid event the University of California Santa Barbara collected a variety of samples from offshore locations. On July 5 gooseneck barnacles from 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*

Waverider buoy and mussels and rock scallop viscera from Platform B contained 19 ppm, <2.5 pm, and 2.6 ppm, respectively. As the domoic acid concentration increased at the aquaculture lease, rock scallop adductor muscle and viscera from Platform Hogan were both below the detection limit on July 11. Also during this event weekly mussel samples from Goleta Pier contained only low levels of domoic acid (7 ppm on August 1). It is noteworthy that there was such a disparity in the maximum toxin concentration between sites, even though Goleta Pier is only three miles from the lease. This observation supports the need for increased offshore sampling as an early indicator of a potential toxic bloom that could impact nearshore fisheries and aquaculture.

Of concern during this event was the high concentration of domoic acid that was detected in a number of fish and crustacean samples along the Ventura coast and from the northern Channel Island chain. Anchovies caught along the Ventura coast in early August contained high levels of domoic acid, ranging from 86 to 155 ppm. In late August four of six crab viscera samples from the Channel Islands contained detectable levels of domoic acid, with two crab well above the alert level (32 ppm and 49 ppm). Samples of lobster viscera collected in August exhibited a similar variability in toxin level, with four of five samples containing domoic acid and three of those above the alert level (46 ppm, 62 ppm, and 140 ppm). The tremendous variability in toxin levels among crab caught in the same pot creates a significant challenge for managing these resources during a HAB event.

This same pattern of variability and elevated toxin levels described for crab near the Channel Islands was also observed in crab samples caught just offshore of Ventura County at the beginning of September. All 12 crab viscera samples contained domoic acid, with four exceeding the alert level (47ppm to 200 ppm). By the end of September all of the crab samples from along the Ventura coast contained low or undetectable levels of domoic acid. However a sample of lobster viscera collected near Port Hueneme contained 51 ppm of domoic acid on September 29. Elevated domoic acid concentrations persisted through the end of the year near the northern Channel Islands. Three of nine crab viscera collected near Santa Rosa Island on December 22 contained domoic acid between 150 and 290 ppm. As noted above, these persistently high toxin concentrations in offshore fisheries point to the need for expanded and routine offshore monitoring.

2012 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

CDPH issued the annual quarantine on the sport-harvesting of mussels on the usual May 1 start date. 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.

CDPH issued a Health Advisory on August 20 advising consumers not to eat recreationally harvested mussels and clams, commercially or recreationally caught anchovy and sardines, or the internal organs of commercially or recreationally caught crab and lobster taken from Ventura County. This action was taken as a result of the elevated levels of domoic acid detected in anchovy, crab and mussels. This advisory was lifted on October 25.

On September 14 CDPH issued an additional Health Advisory for the northern Channel Islands located offshore of Ventura and Santa Barbara counties. Consumers were advised not to eat recreationally harvested mussels and clams, commercially or recreationally caught anchovy and sardines, or the internal organs of commercially or recreationally caught crab and lobster taken from this region.

The annual mussel quarantine ended as usual on midnight October 31 except for Humboldt and Del Norte counties. The quarantine was extended throughout this region because of a significant increase in the PSP toxins.

On November 6 CDPH added sport-harvested clams and whole scallops to the list of Del Norte County bivalve shellfish that consumers should avoid. This was in addition to the annual mussel quarantine that was extended October 31 for both Del Norte and Humboldt counties.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2012.

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TABLES 1 – 7

Table 1. Total number of shellfish samples collected per coastal county in 2012 for PSP assay.

COUNTY	# SAMPLES
Del Norte	9
Humboldt	123
Mendocino	1
Sonoma	24
Marin	407
San Francisco	5
San Mateo	12
Santa Cruz	51
Monterey	1
San Luis Obispo	189
Santa Barbara	157
Ventura	17
Los Angeles	29
Orange	8
San Diego	104
TOTAL	**1137**

Table 2. Number of shellfish samples collected by program participants, per coastal County, in 2012 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	--	5	--	4	9
Humboldt	106	11	2	--	4	123
Mendocino	--	--	1	--	--	1
Sonoma	--	--	23	--	1	24
Marin	385	--	21	--	1	407
San Francisco	--	5	--	--	--	5
San Mateo	--	11	1	--	--	12
Santa Cruz	--	--	49	--	2	51
Monterey	--	--	--	--	1	1
San Luis Obispo	182	--	--	--	7	189
Santa Barbara	101	--	55	1	--	157
Ventura	--	14	--	--	3	17
Los Angeles	--	16	--	--	13	29
Orange	--	1	--	--	7	8
San Diego	44	--	3	49	8	104
TOTAL =	**818**	**58**	**160**	**50**	**51**	**1137**

Table 3. Program participants by county that submitted shellfish samples in 2012 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
	California Department of Fish and Wildlife, Eureka
	Yurok Tribe Environmental Group
	CDPH Food and Drug Branch
Humboldt	Coast Seafoods Company
	Humboldt County Environmental Health Department
	California Department of Fish and Wildlife, Eureka
	CDPH Volunteer
Mendocino	CDPH Food and Drug Branch
Sonoma	CDPH Marine Biotoxin Monitoring Program
	CDPH Volunteer
Marin	CDPH Volunteer
	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
	CDPH Marine Biotoxin Monitoring Program
Santa Cruz	University of California Santa Cruz
	CDPH Volunteer
Monterey	Monterey Abalone Company
San Luis Obispo	Avila Beach Sea Life Center
	CDPH Volunteer
	Grassy Bar Oyster Company
	Morro Bay Oyster Company LLC
Santa Barbara	California Department of Fish and Wildlife, 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
Los Angeles	Los Angeles County Health Department
	City of Los Angeles Environmental Monitoring Division
	CDPH Volunteer
Orange	Orange County Health Care Agency
	CDPH Volunteer
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 2012 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[2]:	
Wild	56
Sentinel	96
Cultured	137
Total Bay Mussels	***289***
Sea Mussels[3]:	
Sentinel	257
Wild	204
Total Sea Mussels	***461***
Total Mussels	**750**
Pacific Oysters[4]	
Cultured	367
Total Oysters	**367**
Other[5]	**22**
TOTAL	**1139**

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

Table 5. Total number of samples analyzed for domoic acid, per coastal county, in 2012.

COUNTY	# SAMPLES
Del Norte	12
Humboldt	23
Mendocino	6
Sonoma	64
Marin	2
San Francisco	0
San Mateo	1
Santa Cruz	50
Monterey	0
San Luis Obispo	98
Santa Barbara	139
Ventura	42
Los Angeles	28
Orange	9
San Diego	53
TOTAL	**527**

Table 6. Total number of phytoplankton samples collected per coastal county in 2012.

COUNTY	# SAMPLES
Del Norte	22
Humboldt	81
Mendocino	25
Sonoma	70
Marin	293
Contra Costa	4
Alameda	5
San Francisco	70
San Mateo	76
Santa Cruz	91
Monterey	99
San Luis Obispo	236
Santa Barbara	187
Ventura	78
Los Angeles	144
Orange	99
San Diego	189
TOTAL	**1769**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2012.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
01/03/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	60
01/03/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	**162**
01/03/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	49
01/03/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #15	40
01/04/12	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	39
01/05/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	**130**
01/05/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	43
01/05/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #8	40
01/05/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	49
01/07/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	54
01/07/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	67
01/07/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #11-O	40
01/07/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	46
01/10/12	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	49
01/11/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	62
01/11/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	**100**
01/11/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #13	36
01/11/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	42
01/14/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	37
01/14/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #15	37
01/14/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	41
01/14/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	53
01/18/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	50
01/18/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
01/24/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	40
01/24/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	37
FEBRUARY				

MARCH				
APRIL				
04/03/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
MAY				
JUNE				
JULY				
AUGUST				
SEPTEMBER				
OCTOBER				
10/02/12	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	41
10/05/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	37
10/15/12	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	37
10/15/12	Humboldt	Sea Mussel, wild	Trinidad Head	43
10/16/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	52
10/23/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	41
10/23/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	**138**
10/25/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	52
10/25/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	**268**
10/26/12	Humboldt	Sea Mussel, wild	Trinidad Head	66
10/29/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	37
10/29/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	56
10/29/12	Del Norte	Sea Mussel, wild	Wilson Creek	**6394**
NOVEMBER				
11/04/12	Humboldt	Sea Mussel, wild	Trinidad, Wash Rock	**450**
11/04/12	Del Norte	Sea Mussel, wild	Point St. George	**1763**
11/05/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
11/05/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	46
11/06/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
11/06/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	36
11/07/12	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	43
11/08/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	42
11/12/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	72

11/13/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	52
11/13/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	38
11/13/12	Marin	Sea Mussel, wild	Kehoe Beach	**148**
11/13/12	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	59
11/13/12	Humboldt	Sea Mussel, wild	Trinidad Head	50
11/13/12	Humboldt	Sea Mussel, wild	Patrick's Point	**103**
11/13/12	Del Norte	Sea Mussel, wild	Wilson Creek	**2574**
11/13/12	Del Norte	Sea Mussel, wild	Wilson Creek	**2765**
11/14/12	San Mateo	Sea Mussel, wild	Pillar Point	38
11/15/12	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	41
11/17/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	36
11/19/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	**124**
11/19/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	**183**
11/19/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	58
11/19/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	**250**
11/19/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
11/19/12	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	44
11/23/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	39
11/25/12	Del Norte	Sea Mussel, wild	Point St. George	**828**
11/26/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	49
11/26/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	45
11/26/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	45
11/26/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	39
11/26/12	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	42
11/26/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	42
11/26/12	Humboldt	Sea Mussel, wild	Trinidad Head	36
11/27/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	36
11/29/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	**118**
11/29/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	45
11/29/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	62
11/29/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	50
11/29/12	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-15	**158**

DECEMBER				
12/03/12	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	43
12/03/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
12/03/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	45
12/03/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	39
12/03/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	53
12/10/12	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	42
12/10/12	Marin	Sea Mussel, Sentinel	Tomales Bay, Lawson's Landing	41
12/10/12	Marin	Sea Mussel, wild	Kehoe Beach	50
12/10/12	Del Norte	Sea Mussel, wild	Wilson Creek	**179**
12/11/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
12/11/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	52
12/11/12	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	55
12/11/12	Sonoma	Sea Mussel, wild	Goat Rock	49
12/11/12	Sonoma	Sea Mussel, wild	Schoolhouse Beach	69
12/13/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	45
12/18/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	64
12/18/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	38
12/18/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	42
12/18/12	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	38
12/26/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	50
12/26/12	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	49
12/26/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	39
12/26/12	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	39

FIGURES 1 – 7.

Figure 1a. Locations of shellfish sampling stations during 2012 (Del Norte to Monterey counties).

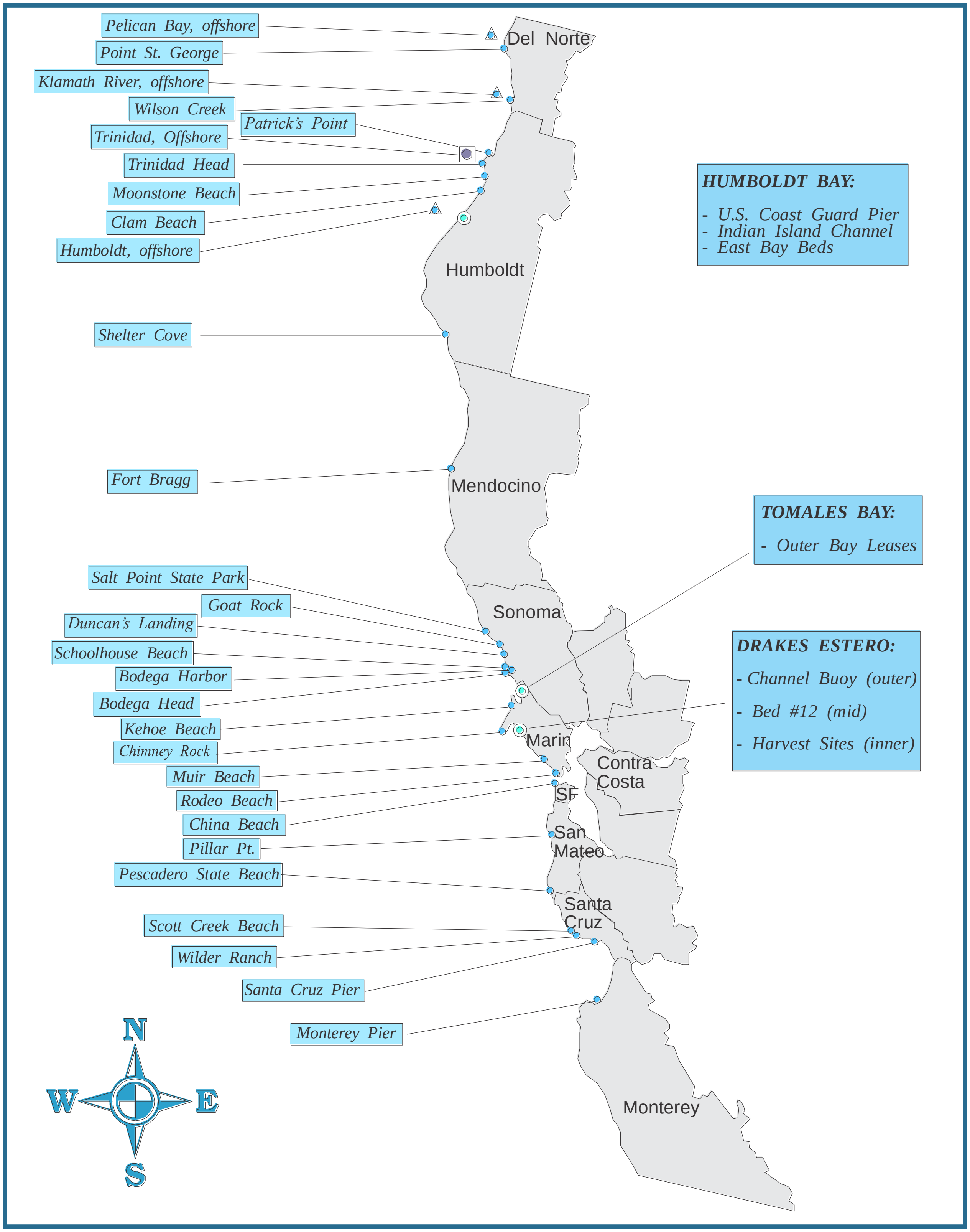

Figure 1b. Locations of shellfish sampling stations during 2012 (San Luis Obispo to San Diego counties).

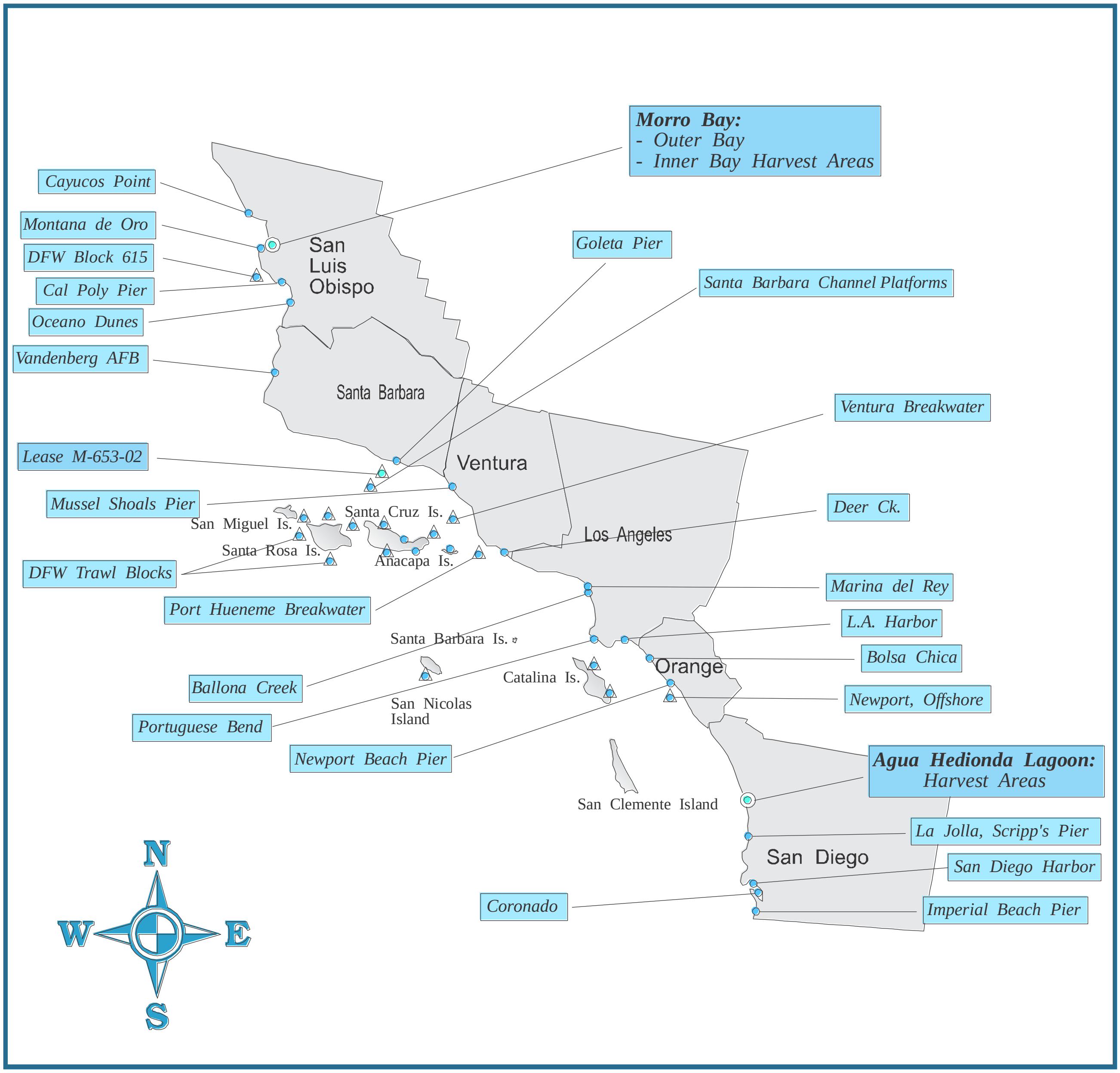

Figure 1c. Locations of phytoplankton sampling stations during 2012 (Del Norte to Monterey counties).

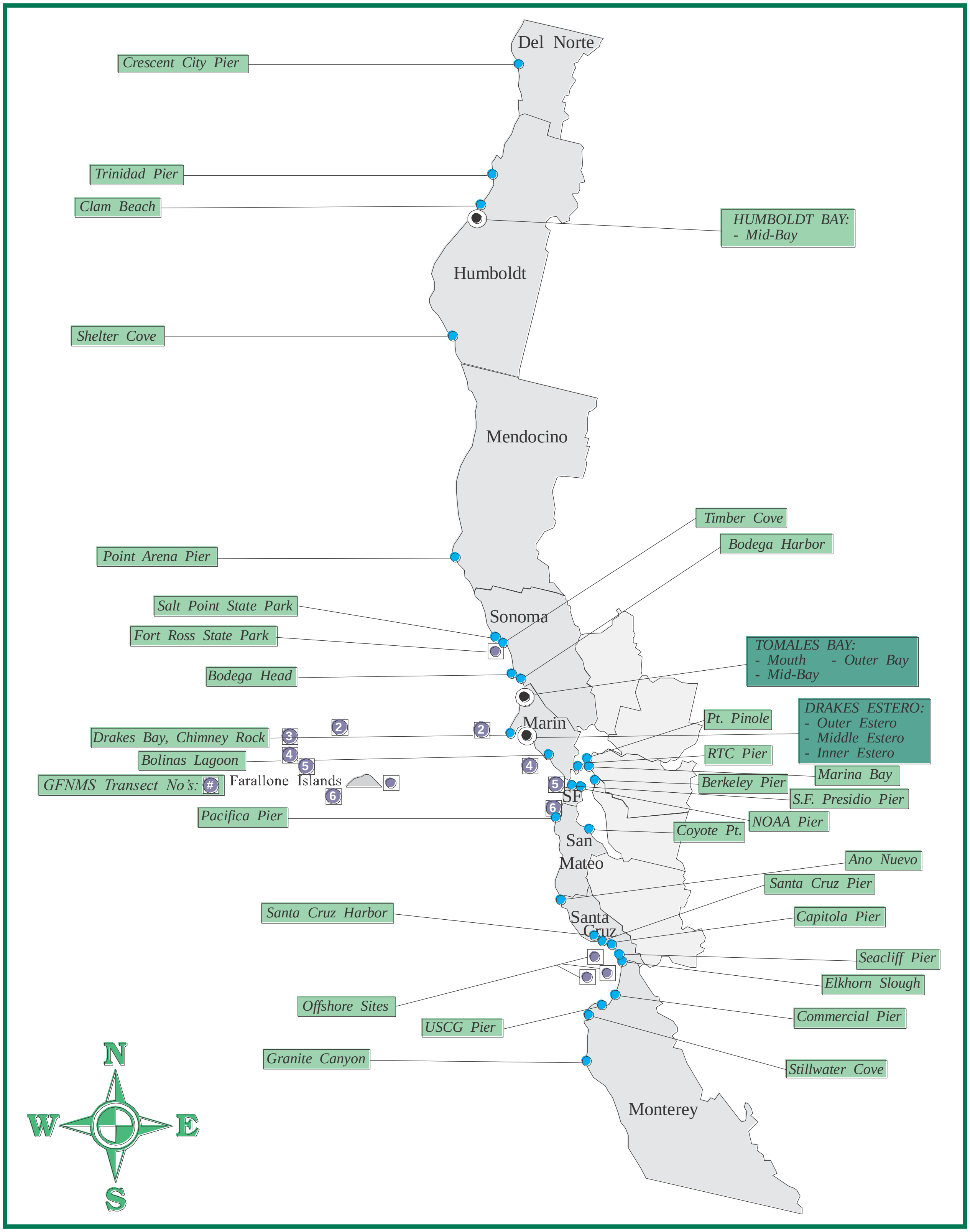

Figure 1d. Locations of phytoplankton sampling stations during 2012 (San Luis Obispo to San Diego counties).

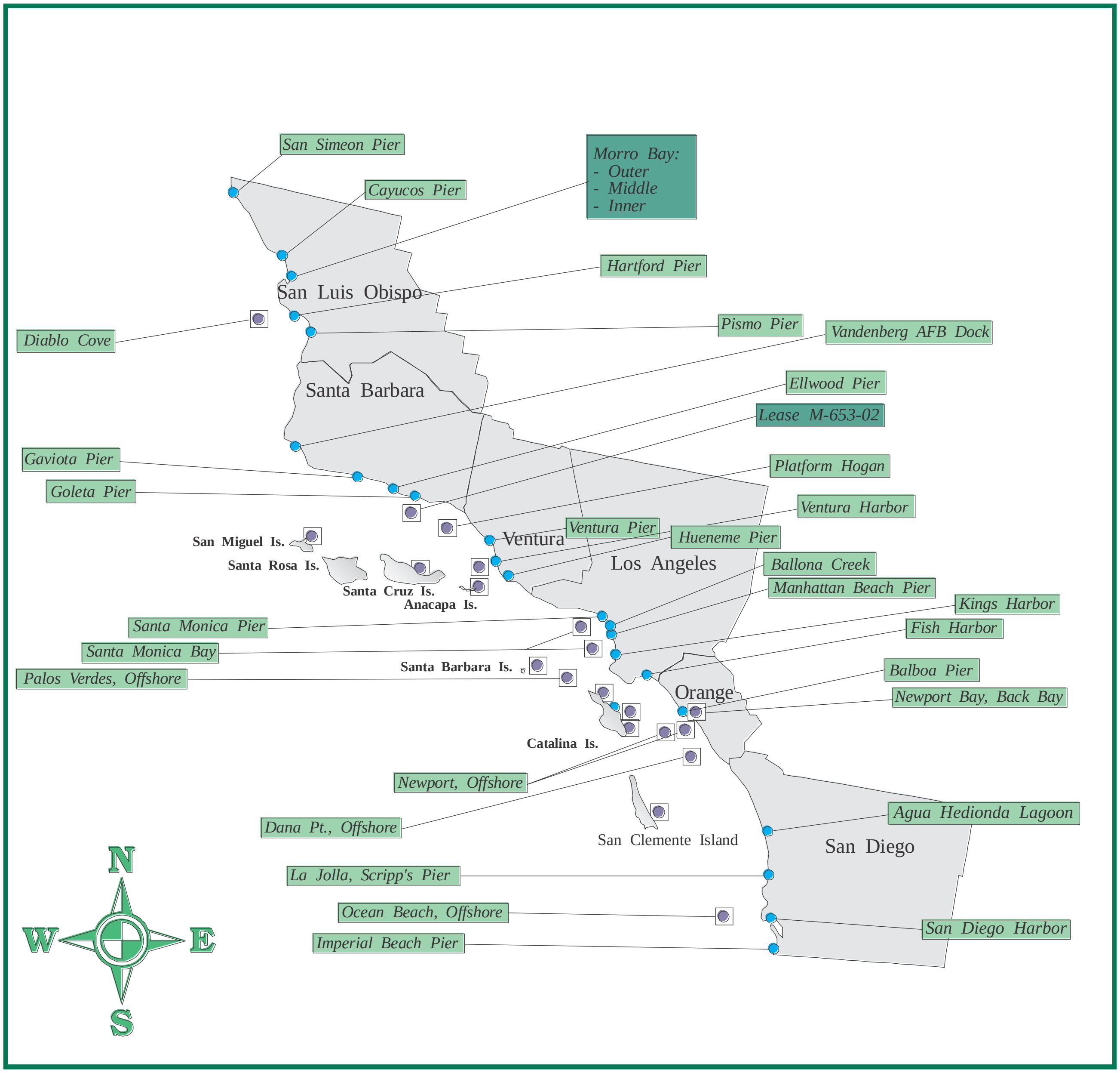

Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2012.

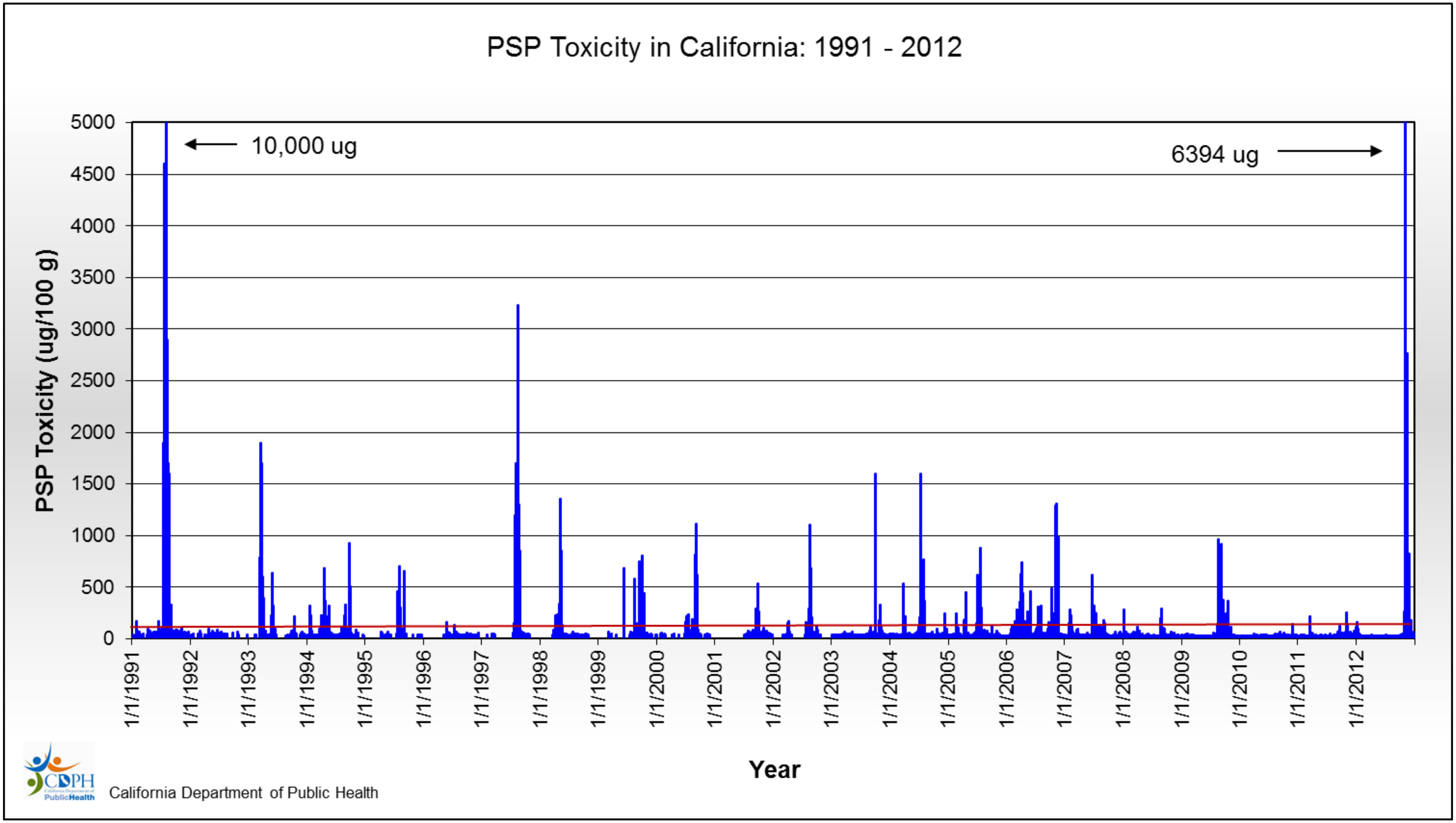

Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2012.

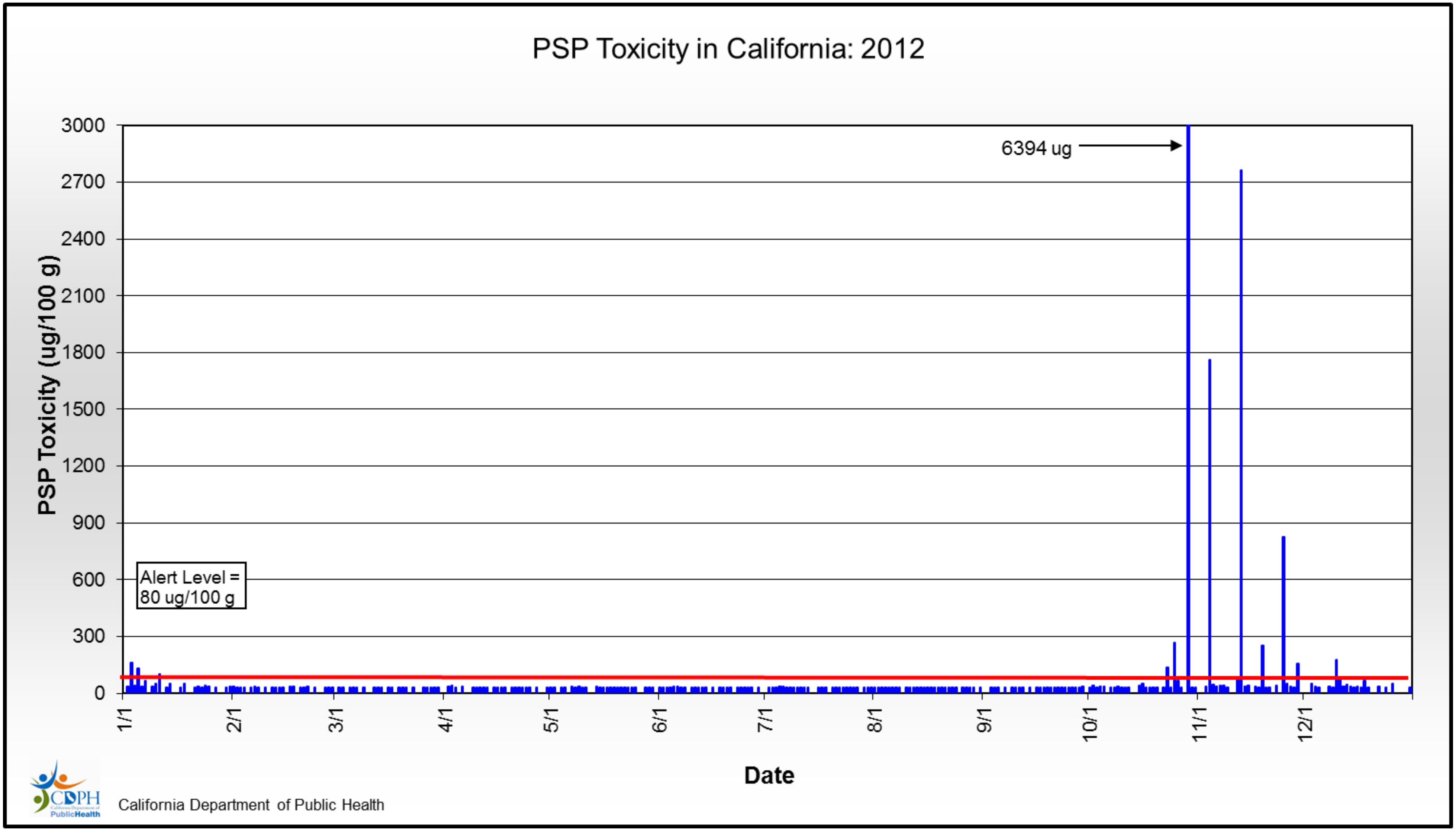

Figure 4. Temporal distribution and percent composition of *Alexandrium spp*. during 2012.

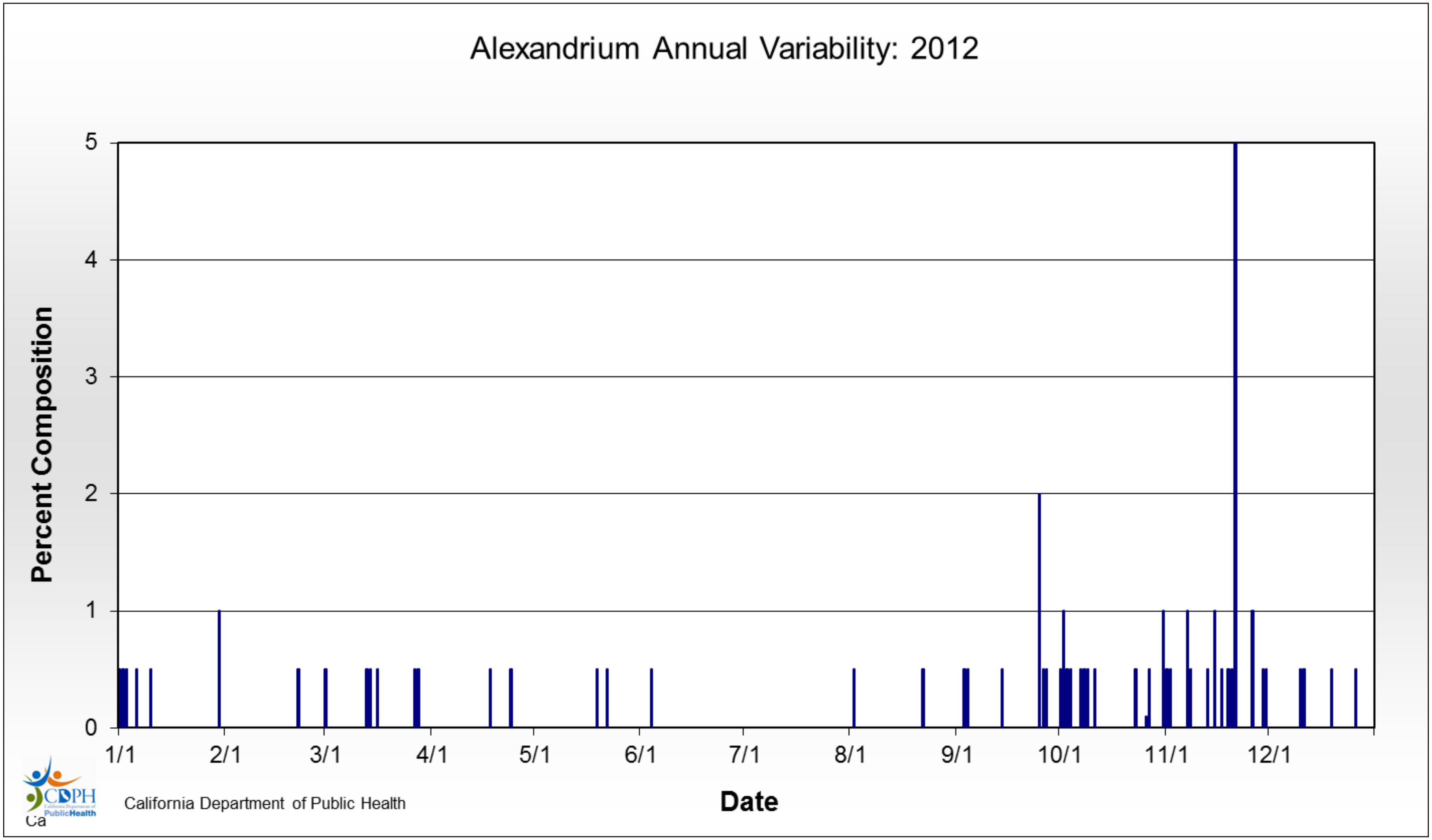

Figure 5. Domoic acid concentration and temporal distribution in California during 2012.

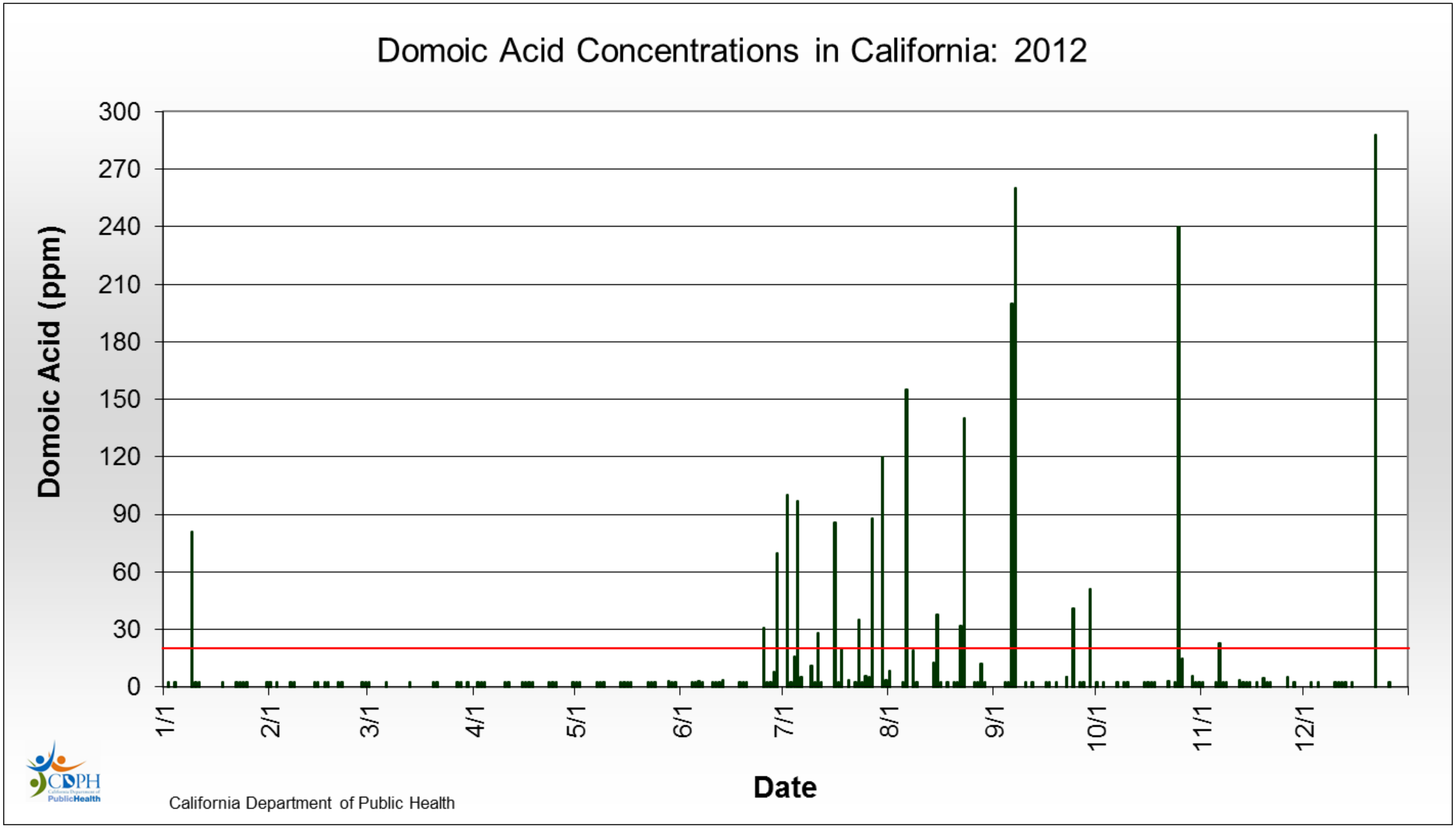

Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia spp*. during 2012.

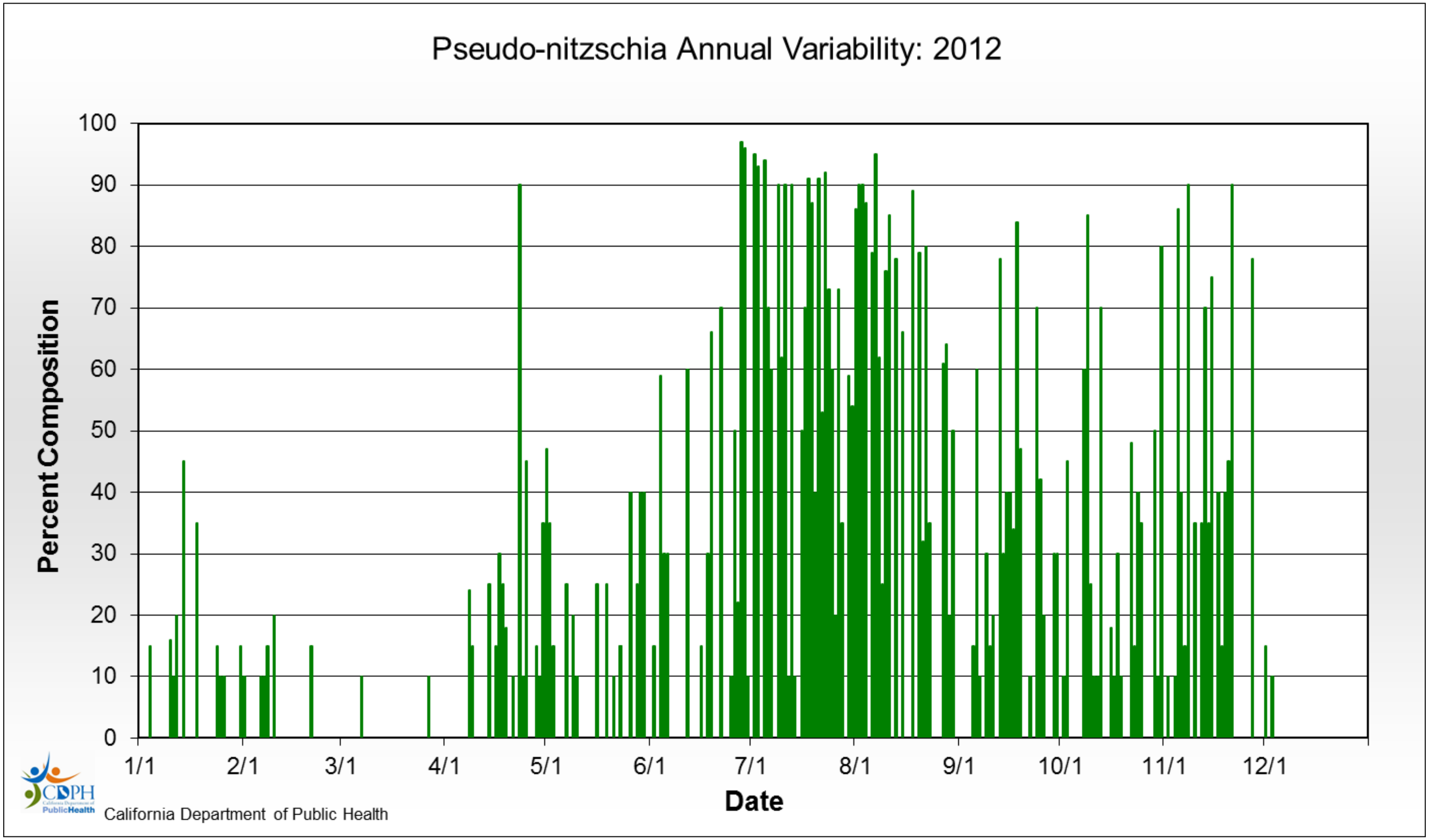

Figure 7. Temporal distribution and relative abundance index (RAI) of *Pseudo-nitzschia spp*. during 2012.