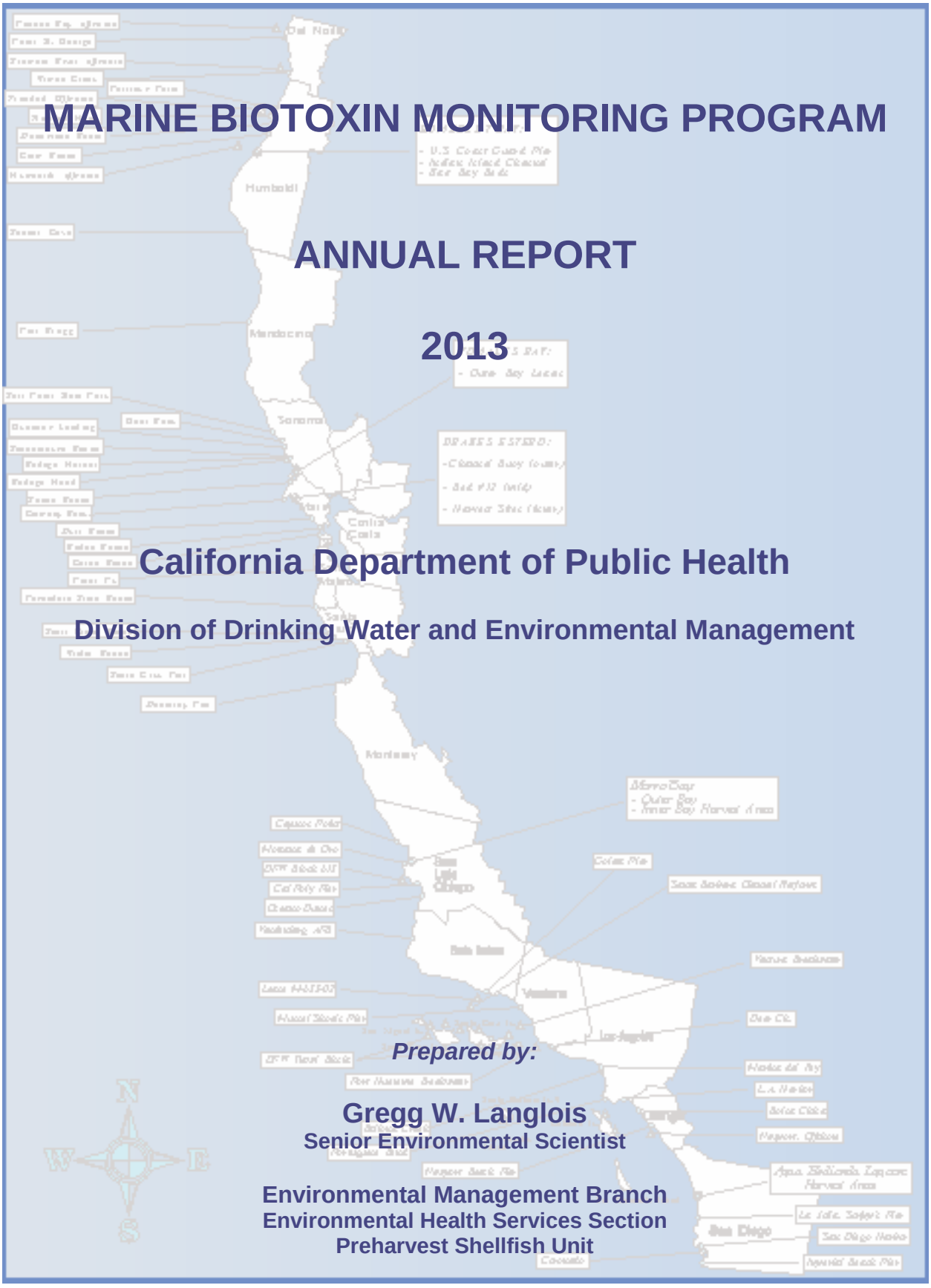
MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2013



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The information in this report represents the efforts of many individuals, including program participants that collect shellfish and phytoplankton samples; California Department of Public Health (CDPH) laboratory scientists responsible for domoic acid and paralytic shellfish poisoning testing; environmental scientists in the CDPH Preharvest Shellfish Unit that manage the monitoring programs and examine phytoplankton samples; food inspectors in the CDPH Food and Drug Branch that collect a variety of seafood samples during a biotoxin event; communications experts in the department's Office of Public Affairs who issue press releases to alert and educate the public; and many others that support these efforts. All of those involved in the CDPH Marine Biotoxin Monitoring Program play a vital role in protecting the public's health.

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The CDPH Marine Biotoxin Monitoring Program would also like to acknowledge the dedicated work and expertise of the scientists 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 an influx of samples resulting 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 are generated on a daily basis by the Marine Biotoxin Monitoring Program thanks to the continuing efforts of our program participants. Additionally, volunteers are collecting phytoplankton samples on a routine basis, increasing their sampling frequency during periods of concern and providing near real-time observations of the occurrence of toxin producing species. These efforts are critical to our ability to monitor phytoplankton distribution and abundance along the California coast. 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 listing of our program participants, provided in each monthly report and in this annual report, illustrates the diversity of groups and individuals that contribute to these efforts.

We would like to express our sincere appreciation to our program participants for all of their efforts. It is through their active participation that CDPH 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 neurologic disturbance 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, a floating sensation, 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, dangerous levels of PSP toxins in shellfish can result from the presence of relatively low numbers of *Alexandrium* in the water that cause no discoloration.

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 oceanographic 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, resulting in a gradual increase in toxin levels. The latter is most common pattern observed during California's PSP events. 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* (Fritz, 1992; Work, 1993).

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, 1989; 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 our efforts to protect public health.

Routine monitoring of the phytoplankton community provides an additional layer of protection because it allows the detection of other toxin-producing species along the California coast that are potentially harmful. 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. Such an event occurred in 2013 and is described below.

2013 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 116 different sites along the coast of California in 2013 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1406 shellfish samples collected statewide for PSP toxin assay during 2013. The greatest number of samples (515) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 92 percent of the samples collected in this County. The majority of these (280) 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 66 percent of all samples collected in 2013, followed by various state agencies and coastal County health departments (15 percent and 7 percent, respectively; Table 2). Several other program participants, including federal agencies, tribes, and citizen volunteers, provided valuable assistance by contributing their sampling effort in 2013. 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, historically, most toxic blooms 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 2013 consisted of mussels (66 percent), followed by pacific oysters (31 percent; Table 4). The Marine Biotoxin Monitoring Program uses 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 California was previously documented (California Department of Health Services, 1991).

Domoic Acid

There were 525 seafood samples analyzed for domoic acid during 2013 compared to 527 samples analyzed the previous year (Table 5). Samples from 78 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 (197) and San Luis Obispo County (73).

Phytoplankton

There were 1944 phytoplankton samples collected during 2013 by our volunteer-based monitoring effort, the largest number of annual samples ever collected by the program. Remarkably, a phytoplankton sample was collected somewhere in California on 329 days of the year. These samples were collected by 87 samplers at 137 sampling sites representing all coastal counties and one County 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 (337), Santa Barbara (250), San Luis Obispo (218), San Diego (195), Los Angeles (151), San Mateo (125), Sonoma (117), Monterey (114), and Orange (106) counties (Table 6).

Of the 1944 phytoplankton samples collected in 2013, 1368 (70 percent) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 125 different sampling sites throughout all of the 15 coastal counties in 2013. The greatest numbers of samples containing toxin-producing species were collected in Marin (216), Santa Barbara (185), San Luis Obispo (175), San Diego (136), and San Mateo (104) counties.

2013 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 Monitoring 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

Alexandrium was observed at sites along most coastal counties during 2013. This dinoflagellate occurred at multiple sites along the California coast during each month except May and June, which had only a single observation each. Of the 131 separate observations of *Alexandrium*, 102 were considered ‘rare’ with respect to the percent composition (<1 percent). Of the 10 samples containing 10 percent or more of *Alexandrium*, seven occurred within Tomales Bay (Marin County) during December. Peak observations of this dinoflagellate occurred at the beginning of the year, in mid-summer, and in December (Figure 2).

The geographic distribution and the frequency of elevated PSP toxin concentrations were higher in 2013 compared to 2012 (Figure 3). As in 2012 the 2013 PSP toxin activity was mostly focused in central and northern California sites, although an unusual

winter event also occurred in Los Angeles. Measurable concentrations of PSP toxins were found in 343 shellfish samples from the following coastal counties: Del Norte, Humboldt, Sonoma, Mendocino, Marin, San Mateo, Santa Cruz, San Luis Obispo, and Los Angeles. Concentrations of PSP toxins greater than or equal to the alert level (80 µg/100 g of tissue) were detected in 95 samples from the following counties: Del Norte, Humboldt, Marin, Santa Cruz, and Los Angeles. The highest PSP toxin concentration occurred in the viscera of rock scallops collected just offshore of Trinidad (Humboldt County), which contained 3926 µg/100 g on August 14. Mussels from Wilson Creek (Del Norte County), collected by the Yurok Tribe Environmental Group, contained 2055 µg/100 g on January 8.

There were three separate episodes of PSP activity in 2013 (Table 7): the continuation of the late 2012 event through February 2013; a summer event centered in parts of Humboldt and Del Norte counties that recorded the highest concentration for the year and produced alert levels of PSP toxins from August through October; and a fall through winter increase in toxicity (Figure 4) that occurred in three distinct regions. The latter episode raises concern about a potential breakdown in the historic seasonal pattern of PSP activity. This is the second year in a row that a significant PSP event occurred in late fall or winter, outside of the traditional quarantine period. In addition this event occurred in three separate geographical areas: Tomales Bay (Marin County), Santa Cruz, and Los Angeles.

Tomales Bay Event

The Tomales Bay episode was also contrary to the normal pattern of transport that is thought to begin with the advection of *Alexandrium* cells from offshore into the nearshore environment. Local conditions then dictate whether these cells are transported inside the various bays and estuaries along the coast. San Francisco Bay, for example, does not have a history of PSP activity and there have been no recorded illnesses from these waters. In contrast, Drakes Bay, and the north-south oriented Drakes Estero that empties into it in a southerly direction, have been the focal point of PSP activity over the past several decades. As a final example, Tomales Bay, which empties into Bodega Bay in a northwesterly direction, is infrequently impacted by the PSP events that cause high toxin levels in shellfish in nearby Drakes Bay and along the Marin coast. Occasionally there will be elevated PSP toxin levels just inside the mouth of Tomales Bay at Lawson's Landing. Less frequently these toxins will be transported the additional one and a half miles inside the bay to the Walker Creek Delta shellfish aquaculture leases, hereafter referred to as the "outer bay". It is extremely rare to see transport of *Alexandrium* farther inside the bay. Prior to 2013 the mussel sampling location at Marconi Cove, approximately 8.5 miles inside the bay, has never experienced PSP toxin concentrations above the alert level.

Persistent low levels of PSP toxins were detected in mussels from outer Tomales Bay from January 11 until April 13. PSP concentrations did not exceed 49 µg/100 g during this interval. Subsequent samples throughout the bay remained below the detection limit until November 15 when a mussel sample from mid-bay at Marconi Cove was reported to contain 37 µg/100 g of PSP toxins. This low level toxicity continued for the next two

weeks. PSP toxins were still undetected in the outer and mid-bay leases by the end of November. In the beginning of December CDPH increased sampling effort from Marconi Cove (lease 430-06) and three additional aquaculture leases farther inside the bay: M-430-19 (0.8 miles), 430-12 (1 mile), and 430-05 (1.8 miles); mid-bay lease 430-14, approximately 3 miles northwest of Marconi Cove was also sampled. On December 2 samples of mussels and oysters from Marconi Cove were reported to contain 241 µg/100 g and 262 µg/100 g, respectively. Oysters from 430-12 contained 61 µg/100 g on this date and samples from the mid and outer bay leases were negative for the PSP toxins. Samples of oysters collected on December 4 from inner bay leases 430-19 and 430-05 contained 445 µg/100 g and 91 µg/100 g, respectively. Mussels and oysters from Marconi Cove contained 588 µg/100 g and 210 µg/100 g, respectively, of the PSP toxins on this date. Additionally, an oyster sample from mid-bay lease 430-14 was positive (39 µg/100 g), the first indication that the PSP toxins were moving from the inner bay towards the outer bay. This possible scenario was reinforced on December 10 when an oyster sample from the outer bay (430-17) was positive for the first time (Figure 5). Concurrently mid-bay lease 430-14 had increased to 70 µg/100 g and, farther inside the bay, shellfish from leases 430-06 and 430-19 had reached 985 µg/100 g and 1008 µg/100 g, respectively. These latter values represent the peak concentrations measured at these sites. The PSP toxin levels continued to increase at the mid-bay and outer bay leases, reaching 813 µg/100 g (December 23) and 203 µg/100 g (December 25), respectively.

The decline in toxin concentrations in Tomales Bay proceeded in reverse order compared to the pattern of increase, with PSP levels decreasing below the alert level in the outer, mid, and inner bay leases by January 2nd, 6th, and 16th, respectively. Various harvest restrictions remained in place for different areas of the bay as toxin levels declined and these controls were not completely removed until February 10, 2014. This PSP event in Tomales Bay was noteworthy for several reasons: (i) the relative abundance of *Alexandrium* at mid- and inner bay sites was the highest observed since monitoring began in 1993; (ii) it was a winter event, contrary to the historic pattern for PSP peak activity in spring and late summer; (iii) this was the first documented occurrence in the mid and inner bay of PSP toxin concentrations above the alert level; and (iv) the initiation of this event was in the inner bay, moving towards the mouth over time, which is contrary to previously established pattern discussed earlier. One question raised by this event concerns the transport of *Alexandrium* to the inner bay where the winter PSP event began. It is unlikely that cells from Bodega Bay could be transported to inner Tomales Bay without impacting the outer and mid-bay shellfish leases. It seems possible that the persistent but minor PSP event documented during the beginning of the year was the source of cells that were transported to the inner bay. Also in question is the mechanism of transport. Hydrographic studies conducted from 1966-70 (Smith, 1971) indicated that the currents in the Bay are predominantly influenced by tidal cycles rather than wind-driven. They suggested that the Bay consists of three regimes, with significant flushing taking place in the outer bay, only sluggish mixing in the mid-bay, and the inner bay taking much less part in the water exchange process. Therefore tidal currents alone would seem unlikely for transport of *Alexandrium* cells to the inner bay. Transport via vessels is possible for small volumes, but the bay is very shallow and

navigated by small skiffs, so ballast water transport is not a significant concern. Shellstock and seed movement occurs between outer bay, mid-bay, and inner bay leases, providing a possible mechanism for transport of *Alexandrium* cells or cysts. Regardless, the occurrence of significant numbers of *Alexandrium* throughout the bay raises a concern about the establishment of cyst beds that could initiate new blooms in different parts of the bay. This would create the need for expanded monitoring to ensure the safety of commercial shellfish operations as well as the recreational clamming that occurs throughout much of Tomales Bay.

Humboldt-Del Norte Event

As noted above, the 2012 PSP event in Humboldt and Del Norte counties extended into March 2013. Although toxins declined below the alert level in March, low levels of the PSP toxins persisted in this region at one or more locations throughout the year, with the exception of Humboldt Bay (Table 7). After April 19 there was no detectable toxin present at the two sentinel mussel stations inside the bay until July 16 when sentinel mussels at the US Coast Guard dock near the bay entrance were again positive for the PSP toxins (40 µg/100 g). PSP levels continued to increase inside the bay at both sentinel stations and at sites along the Humboldt and Del Norte coast. By July 29 mussels from Patrick's Point reached 170 µg/100 g and sentinel mussels from outer Humboldt Bay exceeded the alert level on August 13 (129 µg/100 g). Mussels from the southern portion of Humboldt County at Shelter Cove, which had been well above the alert level in January as part of the fall-winter 2012 event, contained low levels of the PSP toxins but were not observed to exceed the alert level in the fall of 2013. Dangerous levels of the PSP toxins were detected as far north as Point St. George (355 µg/100 g). Mussel samples collected by the Smith River Rancheria at Hunter Rock near the Oregon border had persistent low levels of toxin in September and October. By November the PSP levels had declined below the alert level at most locations, but remained elevated at Stone Lagoon in northern Humboldt County through at least November 14. Low toxin concentrations persisted throughout the remainder of 2013 between Trinidad Head (Humboldt County) and Wilson Creek (Del Norte County).

Los Angeles Event

An unusual increase in the relative abundance of *Alexandrium* was observed in a plankton sample from Los Angeles harbor at the beginning of December. *Alexandrium* was also observed in significant numbers south of Los Angeles harbor at Seal Beach Pier in Orange County. The overall distribution of this dinoflagellate in December extended from offshore of Palos Verdes to Scripps Pier in La Jolla (San Diego County). As a result of the significant cell numbers inside the harbor and the extended range of *Alexandrium,* CDPH alerted program participants and requested additional samples of phytoplankton and shellfish. The Southern California Marine Institute, located in Los Angeles harbor, collected a mussel sample on December 16 from Fish Harbor, which was found to contain 492 µg/100 g of the PSP toxins. PSP toxicity continued to increase, with a follow-up sample collected on December 19 containing 860 µg/100 g. PSP toxicity remained above the alert level at Fish Harbor through early January, declining below the detection level by January 22, 2014. The December samples from this location represent the two highest PSP levels on record for Los Angeles County.

The previous maximum value was 306 µg/100 g from Redondo Beach on March 23, 2006.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

CDPH's volunteer phytoplankton samplers and observers detected significant increases in *Pseudo-nitzschia* at sites representing all coastal counties during 2013. The greatest relative abundances were observed along the Sonoma coast, although no domoic acid was detected in mussel samples from several locations in that region. High relative abundances of *Pseudo-nitzschia* were also observed at sites between Marin and Los Angeles counties. The estimated percent composition of this diatom exceeded 90 percent at sites along each coastal County between Mendocino and Santa Barbara (Figure 6). There was no strong seasonality in the percent composition of this diatom during 2013. As noted above, the RAI index 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, providing some additional insight into the periods and locations of greatest cell numbers. The highest RAI values for *Pseudo-nitzschia* occurred sporadically from late April through mid-October (Figure 7).

The magnitude of domoic acid toxicity in 2013 was less than observed in 2012, with detectable levels of toxin occurring from late April through mid-October, coinciding with the observations of highest relative abundance in *Pseudo-nitzschia* (Figure 8). Measurable concentrations of domoic acid were found in 100 samples during 2013, compared to 149 samples during 2012. Domoic acid was detected in samples from the following coastal counties: Del Norte, Sonoma, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, 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 45 samples from the following four counties: Sonoma (crab viscera), Santa Barbara, Ventura, Los Angeles, and San Diego. Domoic acid concentrations above the alert level were detected in every month of 2013 except for January, June, and July. It should be cautioned that the highest domoic acid concentrations occurred in rock crab viscera, which has had persistently high levels of toxin in the absence of recent *Pseudo-nitzschia* blooms.

Diarhettic Shellfish Poisoning and *Dinophysis* Observations

Several species of the dinoflagellate genus *Dinophysis* are known to produce a number of fat-soluble toxins collectively referred to as diarhettic shellfish poisoning (DSP) toxins. These include okadaic acid (OA), dinophysistoxin-1 (DTX-1) and dinophysistoxin-2 (DTX-2).

On May 12 high cell densities (>50,000 cells/L) of *Dinophysis spp*. were reported at the Cal Poly Pier in Avila Bay. Phytoplankton samples collected by the CDPH network from surrounding sites in San Luis Obispo County did not reveal high numbers of this

dinoflagellate, although several species of *Dinophysis* were present in low numbers. Differences in sampling procedures (e.g., grab sample of surface water for quantitative counting versus a vertical phytoplankton net tow that produces a qualitative sample of the water column) could explain the difference in relative abundance observed. As a precautionary measure CDPH collected mussel samples at the Cal Poly Pier, from outer Morro Bay, and at Goleta Pier in Santa Barbara. The latter location had the greatest numbers of *Dinophysis* observed in CDPH samples, although these were still exceedingly low (<= 2% species composition) compared to the other species present. CDPH also collected phytoplankton samples (concentrated net tow and whole water sample composited over three depths) from the Cal Poly Pier and local rock crab. All samples were analyzed by the U.S. Food and Drug Administration's Gulf Coast Seafood Lab in Alabama for the suite of lipophilic toxins associated with DSP. The FDA lab reported the detection of trace levels of DSP toxins in all mussel and plankton samples, all of which were well below the 0.16 ppm regulatory threshold for DSP toxins. These toxins were not detected in the crab viscera. The highest toxin concentration, 0.04 ppm, was found in the Goleta Pier mussels, corresponding to our phytoplankton observations of higher *Dinophysis* numbers at this location. All three samples of mussels, the concentrated net tow, and the composited whole water sample contained OA and DTX-1; DTX-2 was not found in any sample. Subsequent phytoplankton samples from the affected region did not reveal elevated numbers of *Dinophysis,* therefore additional sampling for DSP analysis was not warranted.

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2013 QUARANTINES AND RELATED HEALTH ADVISORIES

On February 27 CDPH issued a health advisory alerting the public to avoid consuming recreationally harvested mussels, clams, and whole scallops from the Marin County coastline. This advisory was in response to the detection of dangerous levels of PSP toxins in mussels from the region.

On March 15 CDPH rescinded the November 6, 2012 health advisory that warned consumers not to eat any recreationally harvested shellfish from Del Norte County due to high PSP levels. The press release also terminated the extension of the 2012 annual mussel quarantine for Humboldt and Del Norte counties that was related to persistently high PSP toxin concentrations.

CDPH issued the annual quarantine on the sport-harvesting of mussels earlier than usual in 2013, beginning on April 24 due to increasing domoic acid levels and widespread increases in the toxin-producing diatom *Pseudo-nitzschia*. 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.

On October 31 CDPH rescinded the annual mussel quarantine for all coastal counties except for a portion of Humboldt County due to the persistence of elevated PSP toxicity in mussel samples. The affected area was defined as the northern jetty of the Humboldt Bay entrance northward to the Humboldt-Del Norte County line.

CDPH issued a Health Advisory on December 13 advising consumers not to eat recreationally harvested mussels, clams, or whole scallops from inner Tomales Bay or Monterey Bay. This action was taken as a result of the elevated levels of the PSP toxins detected in mussels from both locations as well as oysters from Tomales Bay.

On December 20 CDPH issued an additional Health Advisory to expand the earlier Tomales Bay advisory to include the entire bay. The public was also warned to avoid harvesting and consuming mussels, clams, or whole scallops from the Los Angeles County coastline in the area between Cabrillo Point and the Orange-Los Angeles County line. This advisory was also related to elevated levels of the PSP toxins in mussels.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2013.

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TABLES 1 – 7

Table 1. Total number of shellfish samples collected per coastal County in 2013 for PSP assay.

COUNTY	# SAMPLES
Del Norte	36
Humboldt	165
Mendocino	12
Sonoma	37
Marin	515
San Francisco	1
San Mateo	38
Santa Cruz	54
Monterey	5
San Luis Obispo	204
Santa Barbara	168
Ventura	22
Los Angeles	34
Orange	7
San Diego	108
TOTAL	**1406**

Table 2. Number of shellfish samples collected by program participants, per coastal County, in 2013 for PSP assay.

COUNTY (North to South)	COMMERCIAL SHELLFISH GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL and TRIBAL AGENCIES	OTHER PARTICIPANTS[1]	TOTAL
Del Norte	--	6	7	16[2]	7	36
Humboldt	109	11	24	12[3]	9	165
Mendocino	--	8	3	--	1	12
Sonoma	--	--	33	--	4	37
Marin	474	--	30	--	11	515
San Francisco	--	1	--	--	--	1
San Mateo	--	37	--	--	1	38
Santa Cruz	--	--	47	--	7	54
Monterey	--	--	2	--	3	5
San Luis Obispo	200	--	1	--	3	204
Santa Barbara	96	--	62	8	2	168
Ventura	--	16	1	--	5	22
Los Angeles	--	23	--	--	11	34
Orange	--	2	--	--	5	7
San Diego	47	--	6	48	7	108
TOTAL =	**926**	**104**	**216**	**84**	**76**	**1406**

[1] *Citizen volunteers; City of Los Angeles Environmental Monitoring Division; Amigos de Bolsa Chica*
[2] *Smith River Rancheria, Yurok Tribe Environmental Group*
[3] *Yurok Tribe Environmental Group*

Table 3. Program participants by County that submitted shellfish samples in 2013 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
	California Department of Fish and Wildlife, Eureka
	Smith River Rancheria
	Yurok Tribe Environmental Group
	CDPH Food and Drug Branch
	CDPH Volunteer
Humboldt	Coast Seafoods Company
	Humboldt County Environmental Health Department
	California Department of Fish and Wildlife, Eureka
	Humboldt State University Marine Laboratory
	Yurok Tribe Environmental Group
	CDPH Food and Drug Branch
	CDPH Volunteer
Mendocino	Mendocino County Environmental Health Department
	CDPH Volunteer
	CDPH Food and Drug Branch
Sonoma	CDPH Marine Biotoxin Monitoring Program
	CDPH Volunteer
	CDPH Food and Drug Branch
Marin	CDPH Volunteer
	Cove Mussel Company
	Drakes Bay Oyster Company
	CDPH Marine Biotoxin Monitoring Program
	Hog Island Oyster Company
	Marin Oyster Company
	Point Reyes Oyster Company
	Starbird Mariculture
	Tomales Bay Oyster Company
San Francisco	San Francisco County Health Department
San Mateo	San Mateo County Environmental Health Department
	CDPH Volunteer
Santa Cruz	University of California Santa Cruz

	CDPH Volunteer
Monterey	Monterey Abalone Company
	CDPH Marine Biotoxin Monitoring Program
San Luis Obispo	Avila Beach Sea Life Center
	CDPH Volunteer
	CDPH Marine Biotoxin Monitoring Program
	Grassy Bar Oyster Company
	Morro Bay Oyster Company LLC
Santa Barbara	CDPH Volunteer
	Island Packers/HABNet
	Santa Barbara Mariculture Company
	University of California Santa Barbara/HABNet
	Vandenberg Air Force Base, Environmental Health Services
Ventura	Ventura County Environmental Health Department
	CDPH Volunteer
	University of California Santa Barbara/HABNet
Los Angeles	Los Angeles County Health Department
	City of Los Angeles Environmental Monitoring Division
	CDPH Volunteer
Orange	Orange County Health Care Agency
	CDPH Volunteer
	Amigos de Bolsa Chica
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 2013 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[4]:	
Wild	111
Cultured	201
Total Bay Mussels	***312***
Sea Mussels[5]:	
Sentinel	332
Wild	293
Total Sea Mussels	***625***
Total Mussels	**937**
Pacific Oysters, Cultured[6]	**435**
Other[7]	**34**
TOTAL	**1406**

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

Table 5. Total number of samples analyzed for domoic acid, per coastal County, in 2013.

COUNTY	# SAMPLES
Del Norte	12
Humboldt	5
Mendocino	8
Sonoma	14
Marin	31
San Francisco	0
San Mateo	20
Santa Cruz	39
Monterey	5
San Luis Obispo	73
Santa Barbara	197
Ventura	19
Los Angeles	30
Orange	6
San Diego	66
TOTAL	**525**

Table 6. Total number of phytoplankton samples collected per coastal County in 2013.

COUNTY	# SAMPLES
Del Norte	11
Humboldt	89
Mendocino	30
Sonoma	117
Marin	337
Contra Costa	3
San Francisco	50
San Mateo	125
Santa Cruz	81
Monterey	114
San Luis Obispo	218
Santa Barbara	250
Ventura	66
Los Angeles	151
Orange	106
San Diego	196
TOTAL	**1944**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2013.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
1/2/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	101
1/2/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	153
1/2/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	45
1/2/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	39
1/2/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	39
1/2/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #15	37
1/7/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	113
1/7/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	112
1/8/13	Del Norte	Sea Mussel, wild	Wilson Creek	2055
1/8/13	Del Norte	Sea Mussel, wild	Point St. George	145
1/8/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	43
1/8/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #20	43
1/8/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	42
1/8/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
1/10/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	274
1/10/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	132
1/10/13	Humboldt	Sea Mussel, wild	Trinidad Head	93
1/10/13	Humboldt	Sea Mussel, wild	Humboldt Bay, Outer Breakwater	50
1/10/13	Sonoma	Sea Mussel, wild	Sonoma, Shell Beach	42
1/11/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	44
1/14/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	91
1/14/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	87
1/15/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #41	40
1/15/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	61
1/15/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	50
1/15/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	70
1/17/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	38
1/17/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #15	53

1/17/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	367
1/19/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	373
1/21/13	Humboldt	Sea Mussel, wild	Trinidad, Wash Rock	73
1/21/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	139
1/21/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	372
1/21/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	142
1/22/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	66
1/22/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	199
1/23/13	Del Norte	Sea Mussel, wild	Point St. George	603
1/24/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	69
1/24/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	176
1/24/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	721
1/25/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	42
1/27/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	49
1/27/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	121
1/27/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	297
1/28/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	55
1/28/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	74
1/28/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	50
1/28/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	67
1/28/13	Santa Cruz	Sea Mussel, wild	Santa Cruz, Waddell Beach	58
1/29/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	99
1/29/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	71
1/29/13	Santa Cruz	Sea Mussel, wild	Santa Cruz, Panther Beach	41
1/30/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	272
1/30/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	45
1/30/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	62
1/30/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	41
FEBRUARY				
2/3/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	40
2/3/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	46
2/3/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	41
2/4/13	Humboldt	Sea Mussel, wild	Patrick's Point	183

2/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	73
2/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	58
2/5/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	64
2/5/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	40
2/6/13	Del Norte	Sea Mussel, wild	Crescent City Harbor	37
2/6/13	Humboldt	Sea Mussel, wild	Trinidad Head	63
2/6/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	44
2/6/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	42
2/6/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	41
2/6/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	46
2/7/13	Del Norte	Sea Mussel, wild	Wilson Creek	135
2/7/13	Marin	Sea Mussel, wild	Kehoe Beach	41
2/7/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	41
2/9/13	Del Norte	Sea Mussel, wild	Crescent City, B Street Pier	45
2/9/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	36
2/11/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	44
2/11/13	San Mateo	Sea Mussel, wild	Pillar Point	38
2/11/13	Santa Cruz	Sea Mussel, wild	Santa Cruz, Panther Beach	41
2/12/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	45
2/12/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	60
2/12/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #20	43
2/12/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	65
2/12/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	116
2/12/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	41
2/13/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	41
2/14/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	145
2/14/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #7	36
2/14/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	263
2/14/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	309
2/15/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #1	36
2/15/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	38
2/18/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	872

2/18/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	1076
2/18/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	301
2/19/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	46
2/19/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
2/20/13	Del Norte	Sea Mussel, wild	Crescent City, B Street Pier	42
2/20/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	78
2/20/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	453
2/21/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	312
2/21/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	58
2/21/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	830
2/22/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	49
2/23/13	Humboldt	Sea Mussel, wild	Trinidad, College Cove	40
2/23/13	Sonoma	Sea Mussel, wild	Shell Beach, Sonoma	40
2/24/13	Marin	Sea Mussel, wild	Muir Beach	186
2/25/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	132
2/25/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	45
2/25/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	178
2/25/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	44
2/25/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	73
2/25/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	183
2/25/13	Marin	Sea Mussel, wild	Kehoe Beach	562
2/25/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	46
2/25/13	San Mateo	Sea Mussel, wild	Pillar Point	46
2/26/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	35
2/27/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	49
2/28/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	53
2/28/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	45
2/28/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	37
MARCH				
3/1/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	41
3/3/13	Del Norte	Sea Mussel, wild	Point St. George	67
3/4/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	36

3/4/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	66
3/4/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	60
3/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	36
3/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
3/6/13	Humboldt	Sea Mussel, wild	Palmer's Point	56
3/6/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
3/7/13	Humboldt	Sea Mussel, wild	Stone Lagoon	58
3/7/13	Humboldt	Sea Mussel, wild	Trinidad Head	44
3/7/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	488
3/7/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	190
3/7/13	Marin	Sea Mussel, wild	Kehoe Beach	65
3/7/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	133
3/8/13	Del Norte	Sea Mussel, wild	Wilson Creek	64
3/8/13	Mendocino	Sea Mussel, wild	Fort Bragg, Pudding Creek	37
3/8/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	46
3/8/13	San Mateo	Sea Mussel, wild	Pillar Point	52
3/8/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	46
3/9/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	38
3/9/13	Marin	Sea Mussel, wild	Muir Beach	128
3/11/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	160
3/11/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	42
3/12/13	Del Norte	Sea Mussel, wild	Crescent City, B Street Pier	38
3/12/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	35
3/12/13	Marin	Sea Mussel, wild	Rodeo Beach	47
3/13/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40
3/14/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	198
3/14/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	83
3/16/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	36
3/18/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	37
3/18/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	51
3/18/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	42
3/18/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #7	40

3/19/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
3/20/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40
3/21/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	69
3/21/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	118
3/22/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	36
3/22/13	San Mateo	Sea Mussel, wild	Pillar Point	44
3/23/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	40
3/24/13	Del Norte	Sea Mussel, wild	Pelican State Beach	39
3/25/13	Marin	Sea Mussel, Sentinel	Tomales Bay, Lawson's Landing	36
3/26/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
3/26/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	34
3/26/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #17	55
3/30/13	Humboldt	Sea Mussel, wild	Palmer's Point	52
3/30/13	Humboldt	Sea Mussel, wild	Patrick's Point	41
3/30/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	41
3/31/13	Del Norte	Sea Mussel, wild	Point St. George	41
APRIL				
4/1/13	Del Norte	Sea Mussel, wild	Crescent City, B Street Pier	39
4/1/13	Mendocino	Sea Mussel, wild	Fort Bragg, Pudding Creek	40
4/2/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
4/2/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	38
4/2/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	45
4/2/13	Sonoma	Sea Mussel, Sentinel	Bodega Harbor, USCG Dock	66
4/2/13	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12-O	41
4/2/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	61
4/2/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	35
4/3/13	Del Norte	Sea Mussel, wild	Wilson Creek	44
4/4/13	Mendocino	Sea Mussel, wild	Fort Bragg	38
4/4/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	51
4/5/13	Del Norte	Sea Mussel, wild	Point St. George	57
4/5/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	41
4/5/13	Marin	Sea Mussel, wild	Kehoe Beach	86

4/5/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	36
4/5/13	San Mateo	Sea Mussel, wild	Pillar Point	39
4/6/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	45
4/7/13	Humboldt	Sea Mussel, wild	Trinidad Head	38
4/9/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	37
4/9/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	39
4/9/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	41
4/13/13	Del Norte	Sea Mussel, wild	Crescent City Harbor	36
4/13/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	34
4/16/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	35
4/19/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	42
4/23/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	38
4/24/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	43
4/26/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	37
MAY				
5/1/13	Del Norte	Sea Mussel, wild	Wilson Creek	47
5/1/13	Humboldt	Sea Mussel, wild	Patrick's Point	37
5/1/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	39
5/2/13	Humboldt	Sea Mussel, wild	Stone Lagoon	38
5/13/13	Del Norte	Sea Mussel, wild	Point St. George	40
5/30/13	Del Norte	Sea Mussel, wild	Wilson Creek	38
5/31/13	Humboldt	Sea Mussel, wild	Stone Lagoon	40
JUNE				
6/25/13	Del Norte	Sea Mussel, wild	Point St. George	39
6/26/13	Del Norte	Sea Mussel, wild	Wilson Creek	42
6/27/13	Humboldt	Sea Mussel, wild	Stone Lagoon	40
JULY				
7/16/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
7/23/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	62
7/23/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	46
7/25/13	Del Norte	Sea Mussel, wild	Point St. George	59
7/26/13	Del Norte	Sea Mussel, wild	Wilson Creek	52

7/26/13	Del Norte	Sea Mussel, wild	* Experiment *	37
7/26/13	Humboldt	Sea Mussel, wild	Stone Lagoon	48
7/29/13	Humboldt	Sea Mussel, wild	Patrick's Point	170
7/29/13	San Luis Obispo	Bay Mussel, wild	Morro Bay, North T-Pier	39
7/30/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	72
7/30/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	43
AUGUST				
8/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
8/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	61
8/5/13	San Luis Obispo	Bay Mussel, wild	Morro Bay, North T-Pier	39
8/6/13	Humboldt	Sea Mussel, wild	Trinidad Head	293
8/13/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	129
8/13/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
8/14/13	Humboldt	Rock Scallop viscera	Trinidad Head	3926
8/20/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
8/20/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	63
8/20/13	Humboldt	Sea Mussel, wild	Palmer's Point	516
8/22/13	Del Norte	Sea Mussel, wild	Point St. George	355
8/23/13	Del Norte	Sea Mussel, wild	Wilson Creek	341
8/23/13	Humboldt	Sea Mussel, wild	Trinidad Head	199
8/27/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	48
8/27/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	41
SEPTEMBER				
9/3/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	41
9/5/13	Del Norte	Sea Mussel, wild	Hunter Rock, north	56
9/10/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
9/17/13	Del Norte	Sea Mussel, wild	Wilson Creek	106
9/17/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
9/17/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	46
9/17/13	Humboldt	Sea Mussel, wild	Stone Lagoon	58
9/17/13	Humboldt	Sea Mussel, wild	Stone Lagoon	661
9/17/13	Humboldt	Sea Mussel, wild	Stone Lagoon	893

9/19/13	Humboldt	Sea Mussel, wild	Trinidad Head	55
9/24/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	56
9/24/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	49
9/25/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	36
OCTOBER				
10/1/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	87
10/1/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
10/2/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	53
10/4/13	Humboldt	Sea Mussel, wild	Patrick's Point	242
10/6/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	43
10/6/13	Humboldt	Sea Mussel, wild	Trinidad, Camel Rock	144
10/8/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	46
10/8/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	41
10/9/13	Del Norte	Sea Mussel, wild	Wilson Creek	57
10/9/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	58
10/15/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	38
10/15/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	37
10/16/13	Humboldt	Sea Mussel, wild	Stone Lagoon	216
10/16/13	San Mateo	Sea Mussel, wild	Pescadero State Beach	40
10/16/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	44
10/17/13	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	38
10/18/13	Del Norte	Sea Mussel, wild	Point St. George	67
10/18/13	Humboldt	Sea Mussel, wild	Trinidad Head	44
10/20/13	Santa Cruz	Sea Mussel, wild	Santa Cruz, Scott Creek Beach	48
10/22/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	37
10/24/13	Mendocino	Sea Mussel, wild	Fort Bragg, Pudding Creek	36
10/25/13	Humboldt	Sea Mussel, wild	Stone Lagoon	87
10/30/13	Del Norte	Sea Mussel, wild	Hunter Rock, north	44
10/30/13	Humboldt	Sea Mussel, wild	Palmer's Point	59
NOVEMBER				
11/5/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	35
11/6/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40

11/12/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	36
11/13/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	73
11/14/13	Humboldt	Sea Mussel, wild	Stone Lagoon	125
11/14/13	Sonoma	Sea Mussel, wild	Schoolhouse Beach	36
11/15/13	Del Norte	Sea Mussel, wild	Wilson Creek	50
11/15/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	37
11/18/13	Humboldt	Sea Mussel, wild	Shelter Cove, Abalone Pt.	38
11/19/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	36
11/20/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	43
11/21/13	Santa Cruz	Sea Mussel, wild	Santa Cruz, Scott Creek Beach	49
11/25/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	39
11/25/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	37
11/27/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	544
DECEMBER				
12/1/13	Humboldt	Sea Mussel, wild	Patrick's Point	43
12/2/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	241
12/2/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-06-O	262
12/2/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-12	61
12/3/13	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	37
12/4/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-05	91
12/4/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-19	445
12/4/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	39
12/4/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-06-O	210
12/4/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	588
12/4/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	585
12/9/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-06-O	105
12/9/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	985
12/10/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	70
12/10/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-17	36
12/10/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-05	63
12/10/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	36
12/10/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-19	1008

12/11/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	656
12/12/13	Del Norte	Sea Mussel, wild	Wilson Creek	44
12/12/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	219
12/12/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	38
12/13/13	Humboldt	Sea Mussel, wild	Stone Lagoon	42
12/16/13	Humboldt	Sea Mussel, wild	Trinidad Head	39
12/16/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-17	54
12/16/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	685
12/16/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-06-O	145
12/16/13	Los Angeles	Bay Mussel, wild	Long Beach, Fish Harbor	492
12/17/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-05	42
12/17/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	45
12/17/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-19	700
12/18/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-17	69
12/18/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	609
12/18/13	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	111
12/19/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	38
12/19/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	48
12/19/13	Los Angeles	Bay Mussel, wild	Long Beach, Fish Harbor	860
12/20/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-04-O	121
12/20/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11-O	67
12/20/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-15	36
12/22/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	34
12/23/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	813
12/23/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-17	54
12/23/13	Marin	Sea Mussel, Sentinel	Tomales Bay, Lawson's Landing	122
12/25/13	Marin	Bay Mussel, cultured	Tomales Bay, Lease #M430-06-M	259
12/25/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-06-O	57
12/25/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-04-O	203
12/26/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-05	40
12/28/13	Marin	Sea Mussel, wild	Stinson Beach, south rocks	36
12/29/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12-M	40

12/29/13	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	47
12/29/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-17	92
12/29/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-14	375
12/30/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-04-O	62
12/30/13	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-19	207

FIGURES 1 – 8.

Figure 1a. Locations of shellfish sampling stations during 2013 (Del Norte to Monterey counties).

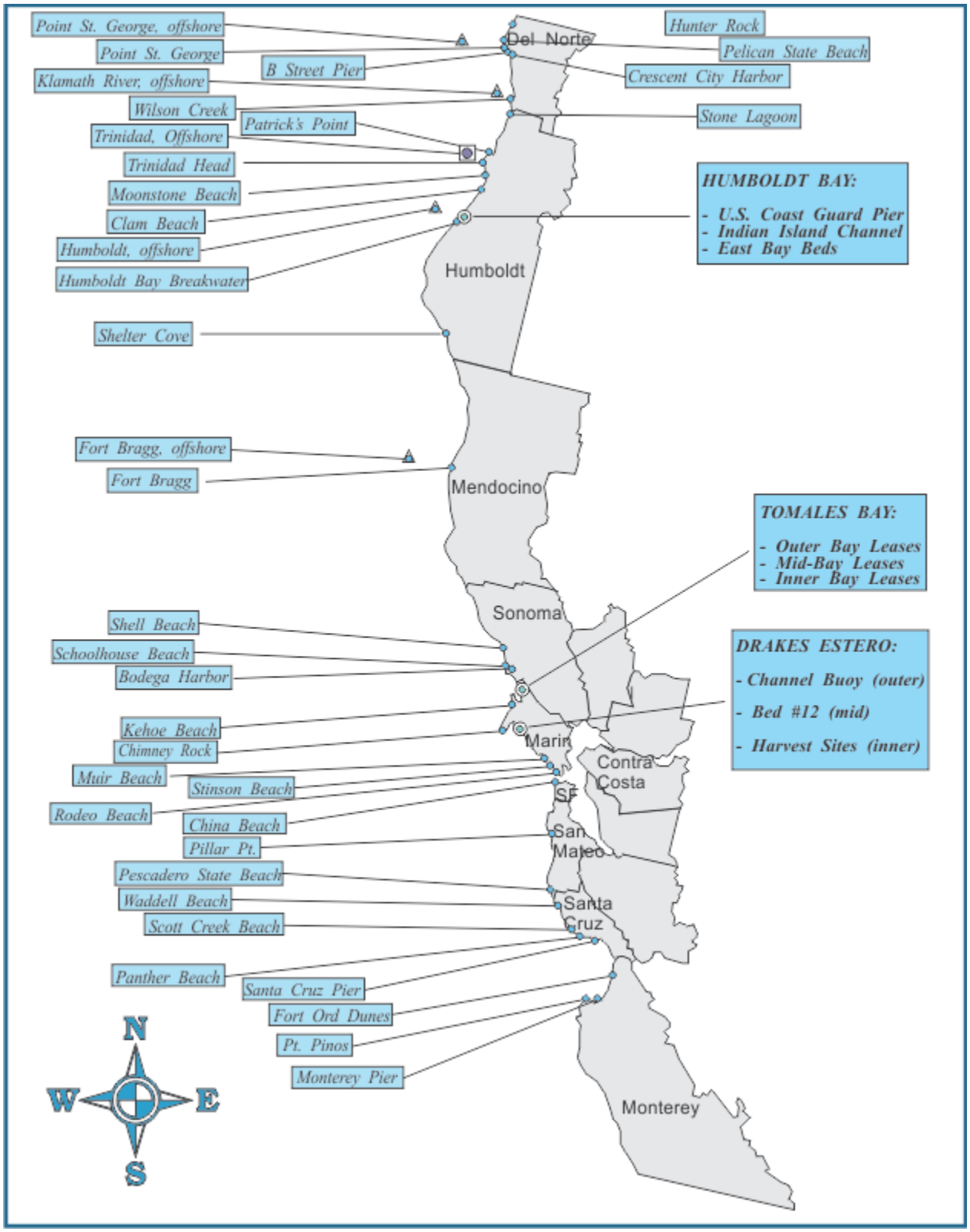

Figure 1b. Locations of shellfish sampling stations during 2013 (San Luis Obispo to San Diego counties).

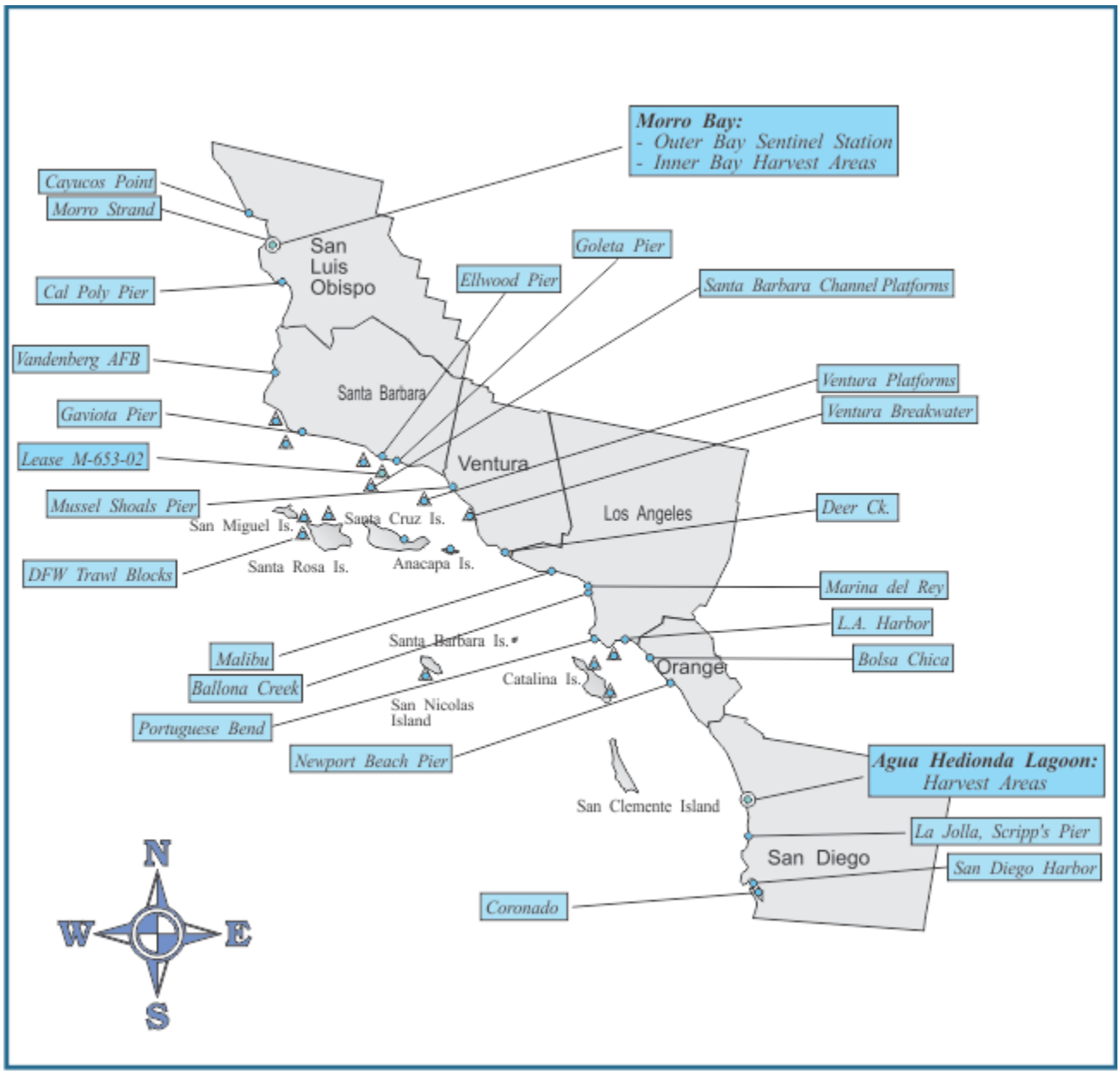

Figure 1c. Locations of phytoplankton sampling stations during 2013 (Del Norte to Monterey counties).

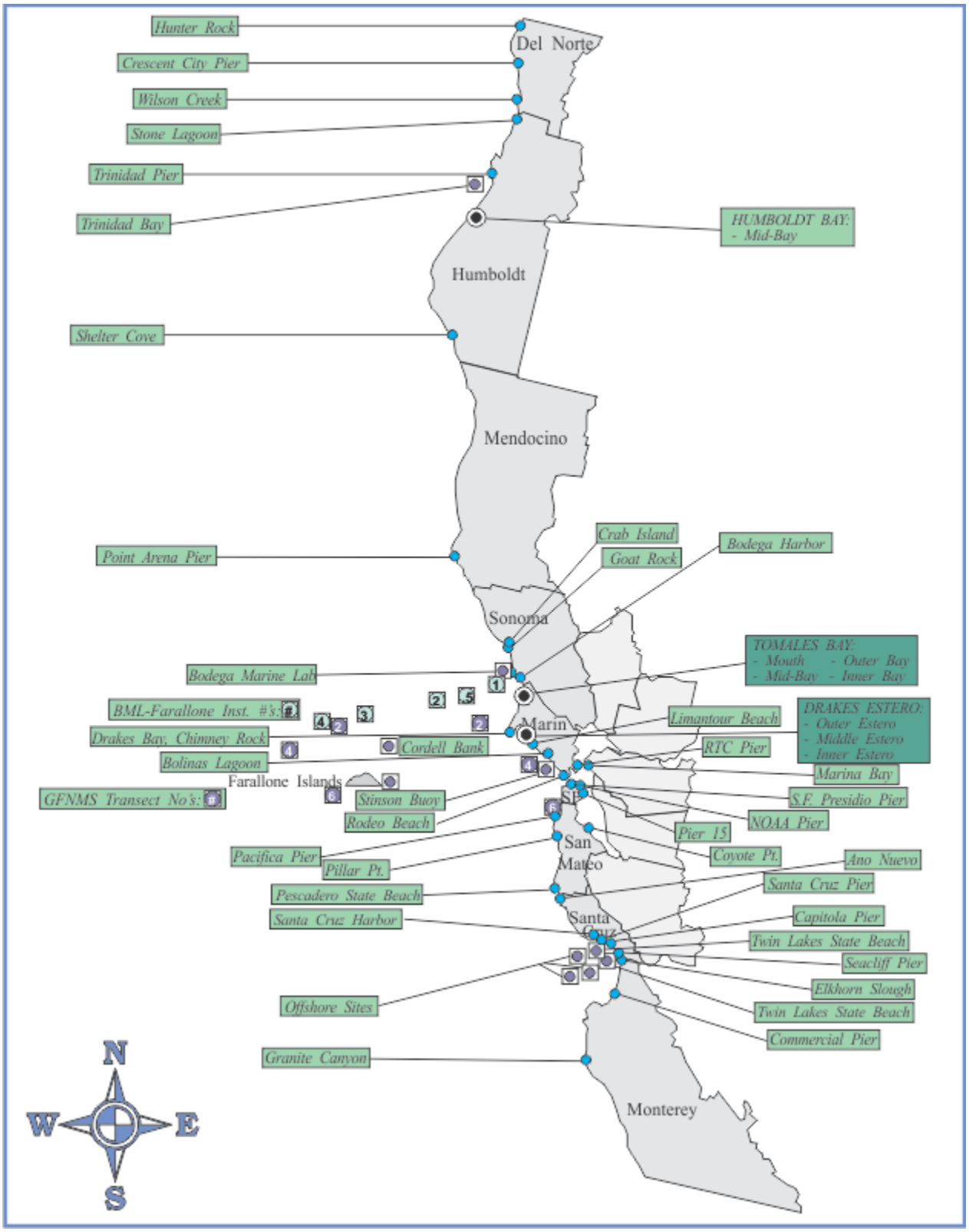

Figure 1d. Locations of phytoplankton sampling stations during 2013 (San Luis Obispo to San Diego counties).

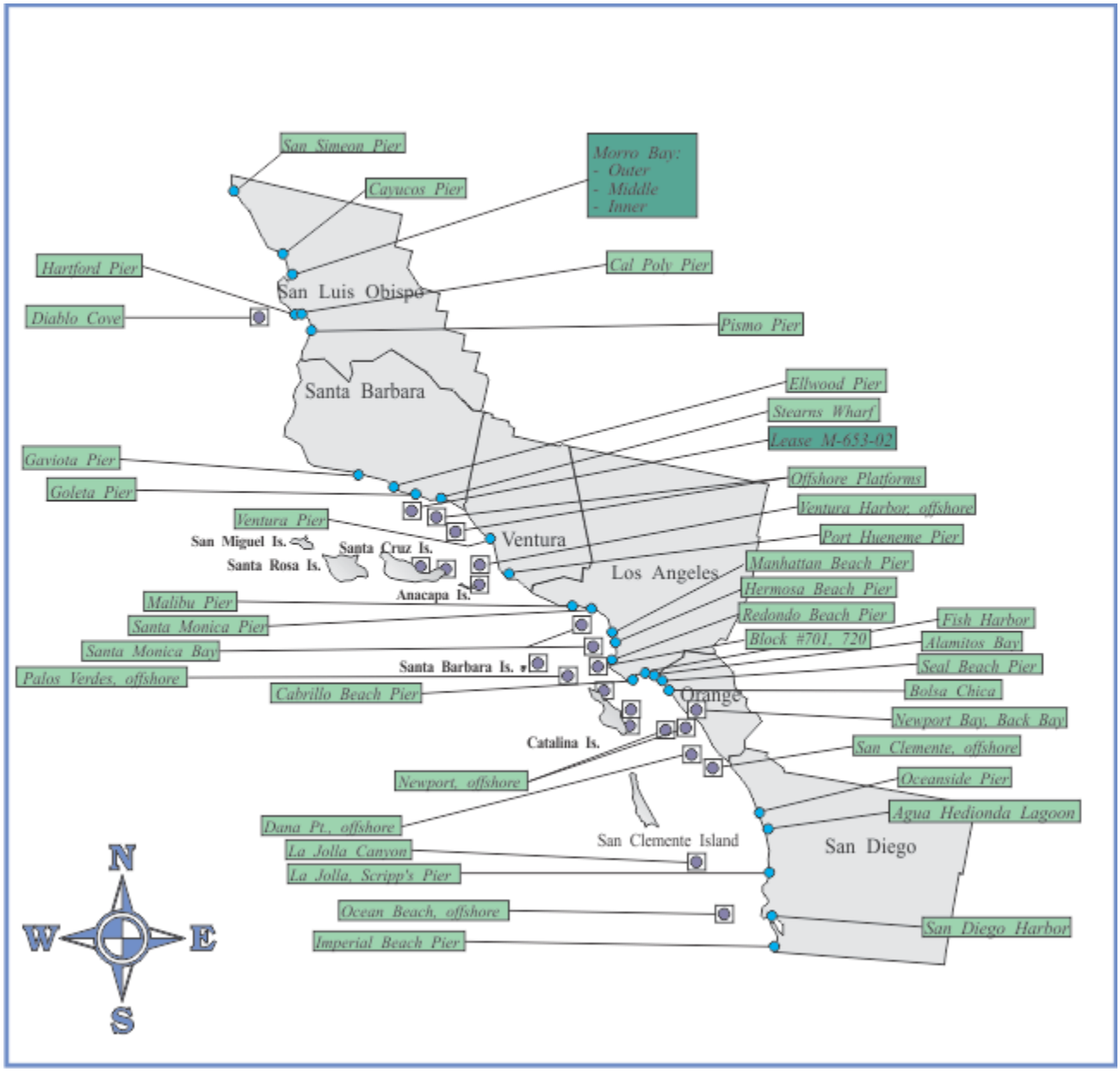

Figure 2. Temporal distribution and percent composition of *Alexandrium spp*. during 2013.

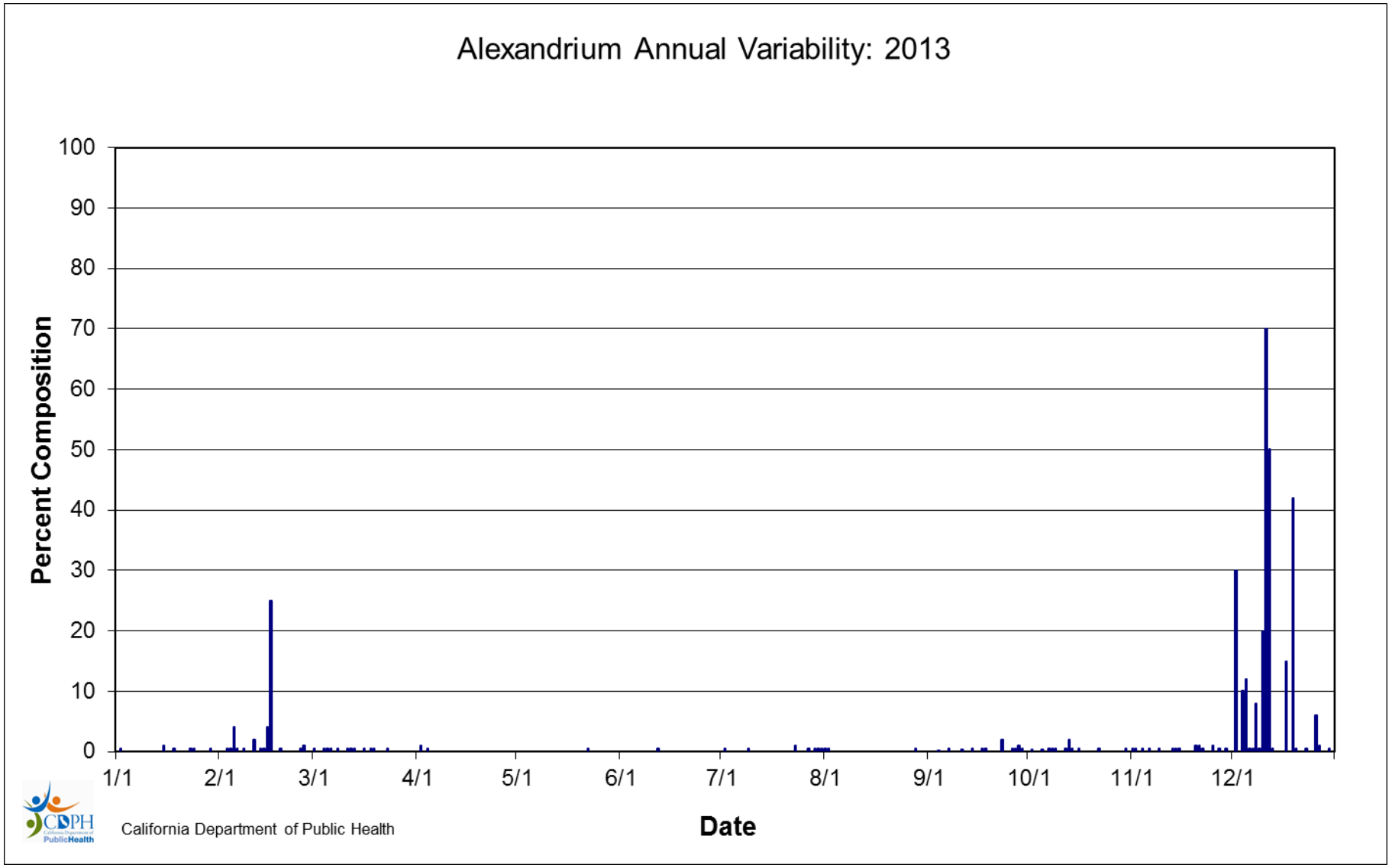

Figure 3. Annual PSP toxin levels in California shellfish from 1991 through 2013.

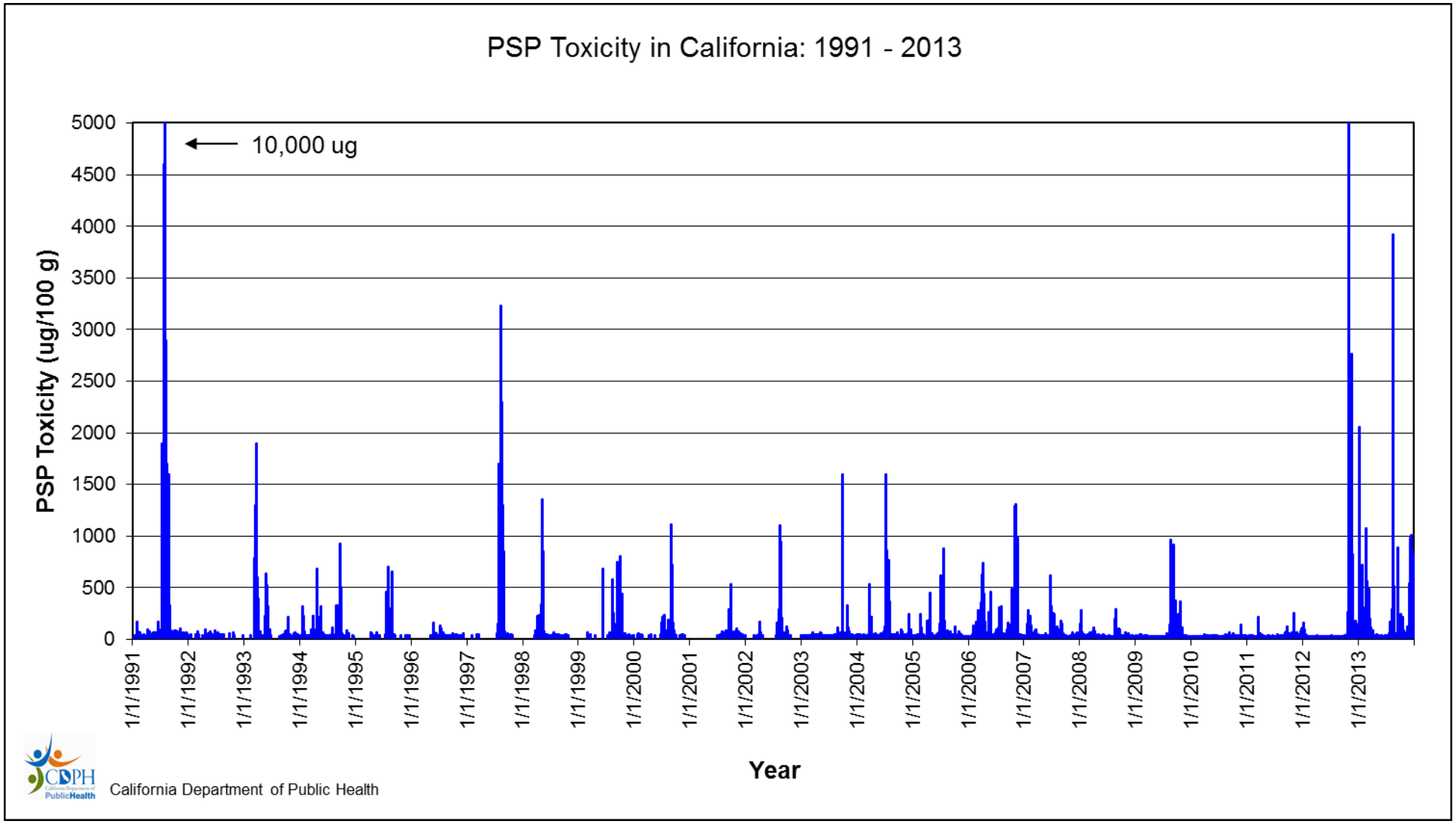

Figure 4. PSP toxin concentration and temporal distribution in California shellfish during 2013.

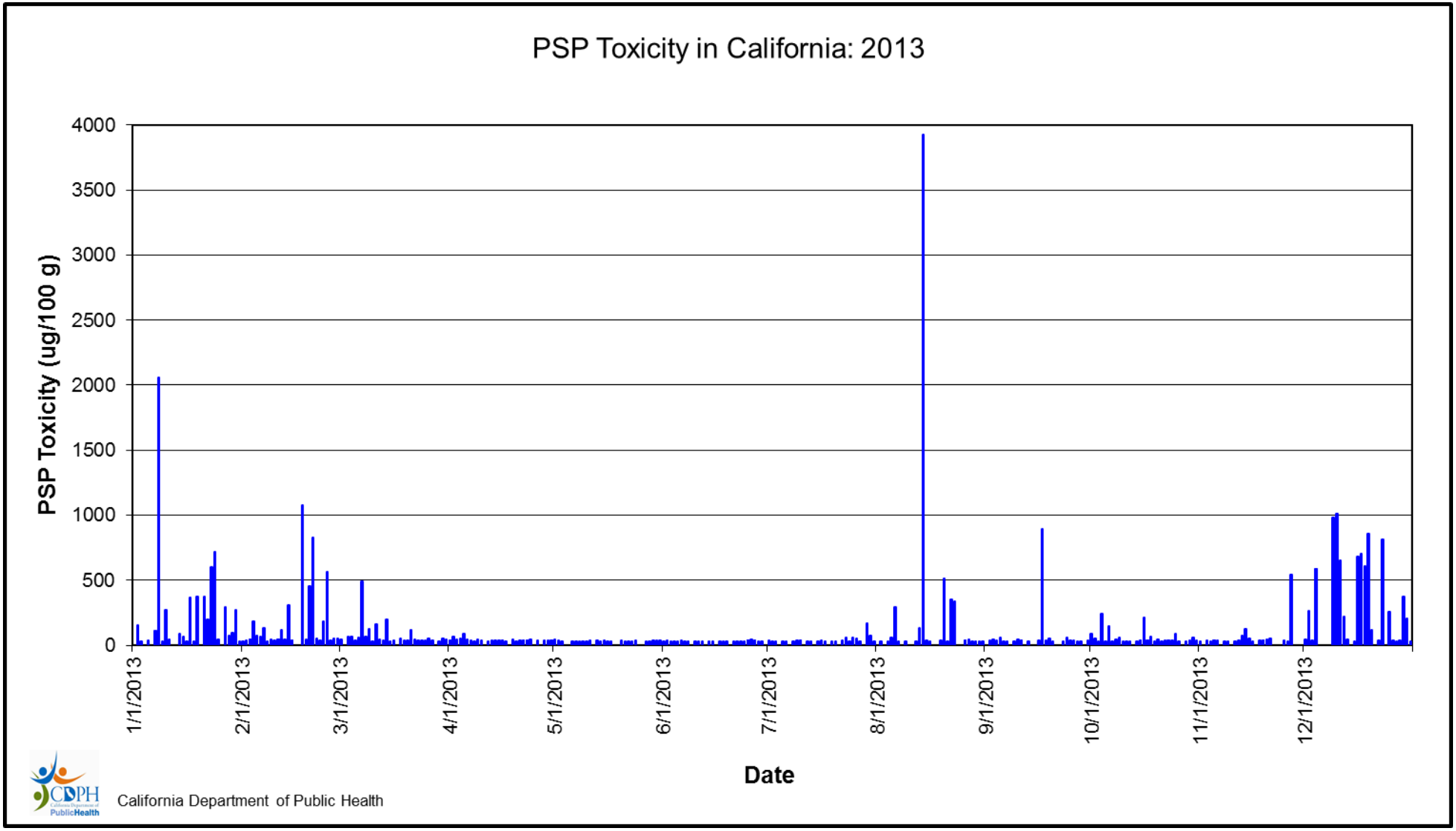

Figure 5. Temporal and geographic distribution of PSP toxins inside Tomales Bay during the 2013 winter event.

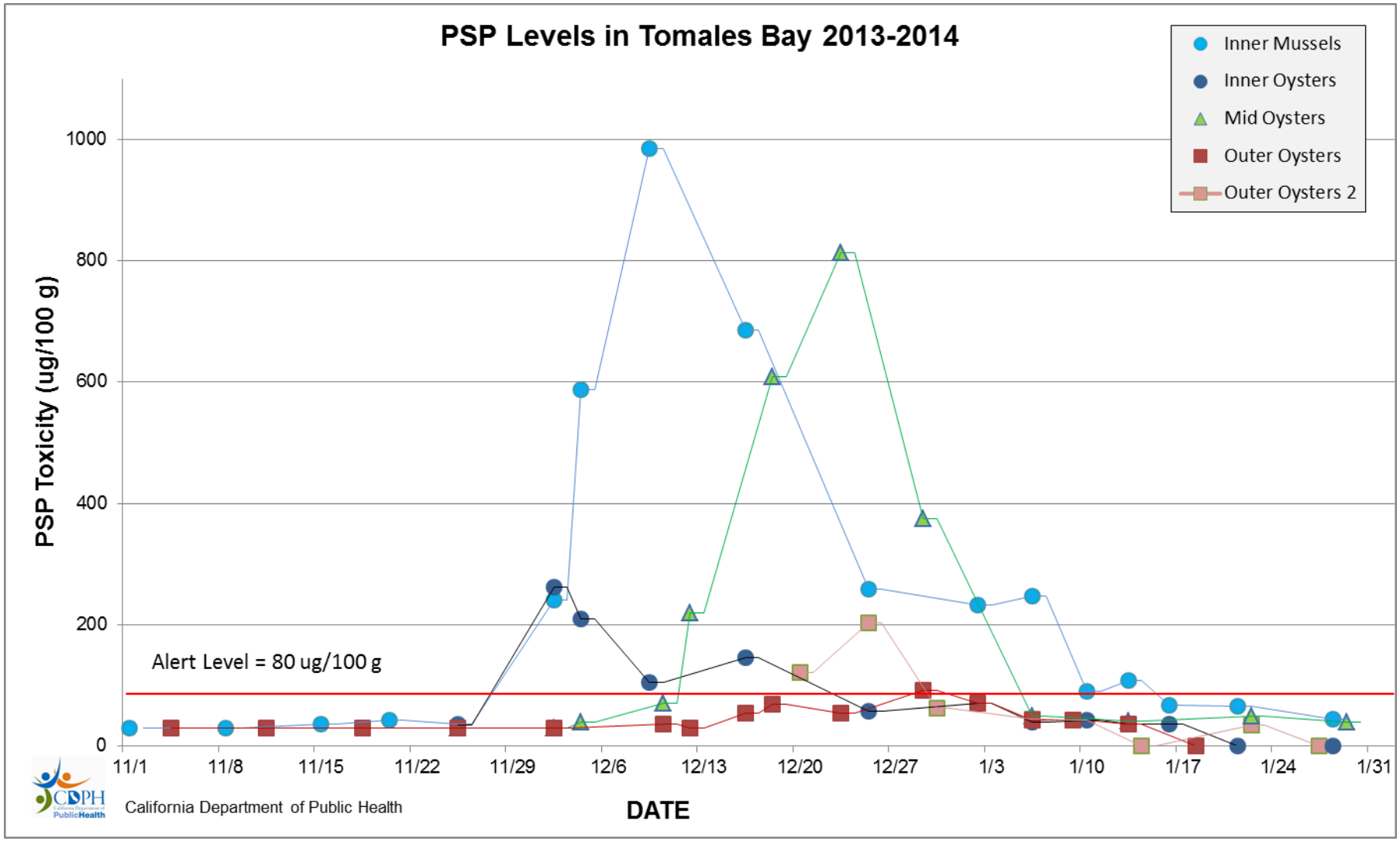

Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia spp*. during 2013.

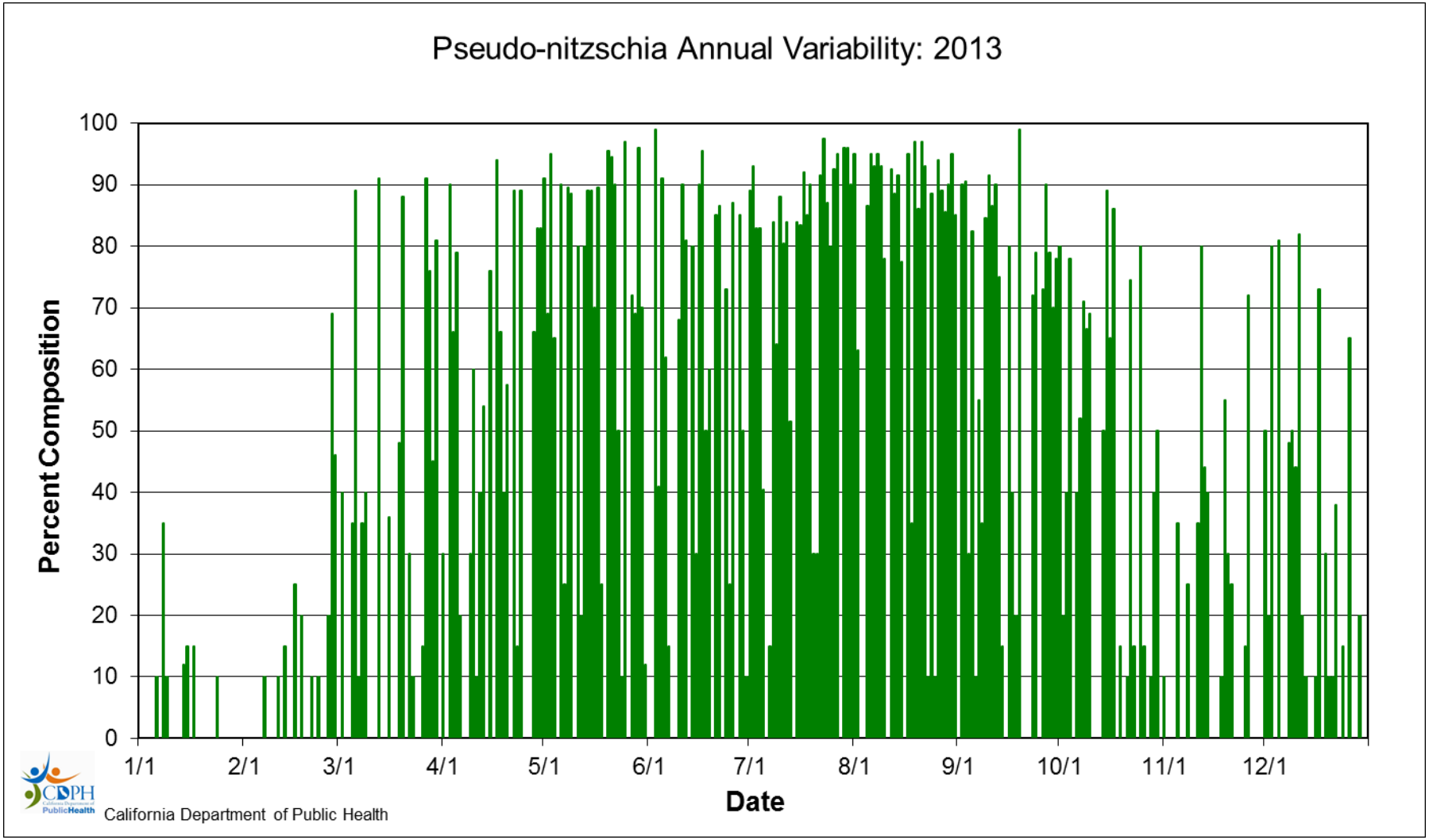

Figure 7. Temporal distribution and relative abundance index (RAI) of *Pseudo-nitzschia spp*. during 2013.

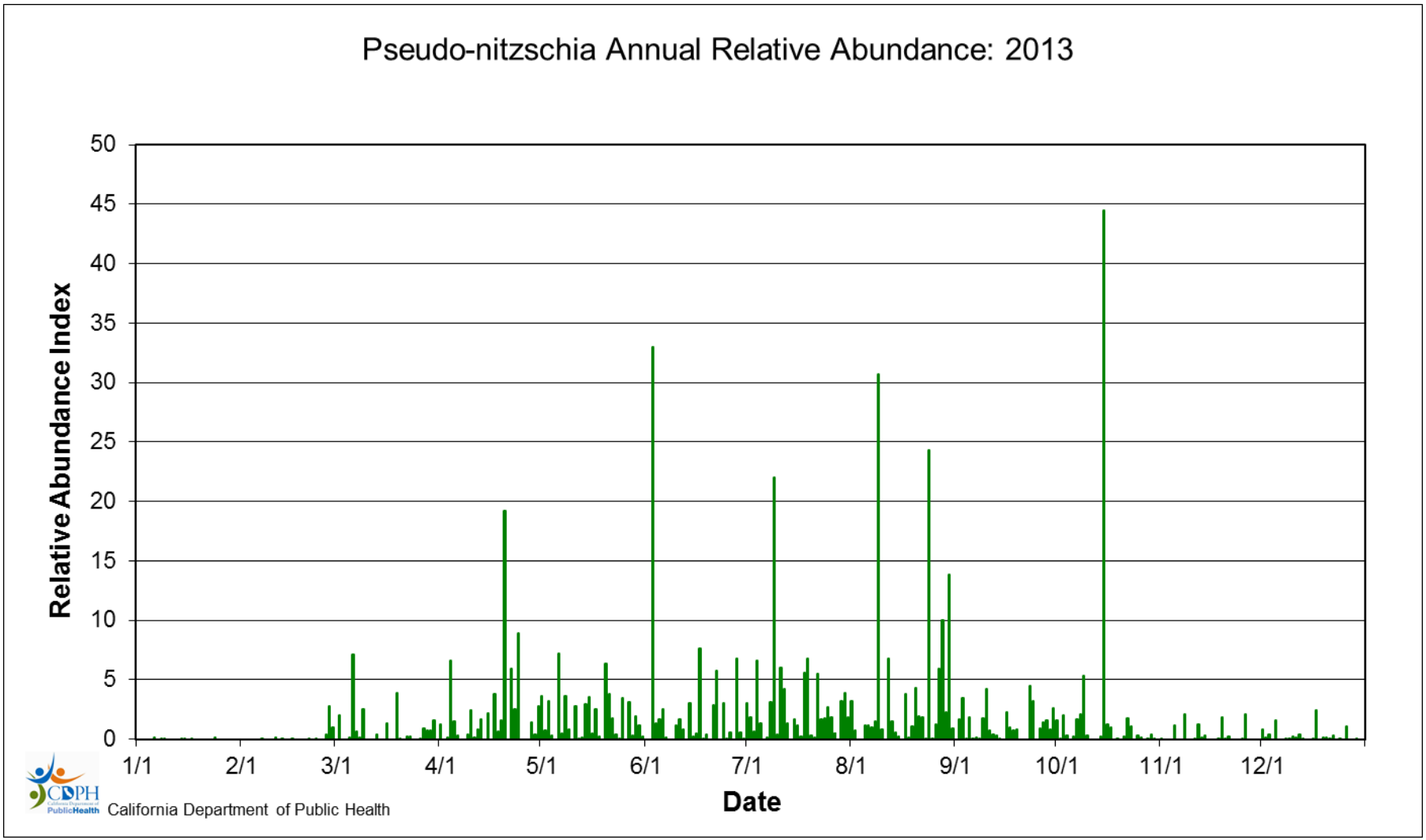

Figure 8. Domoic acid concentration and temporal distribution in California during 2013.