MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2004

Submitted to:

California Department of Fish and Game

By:

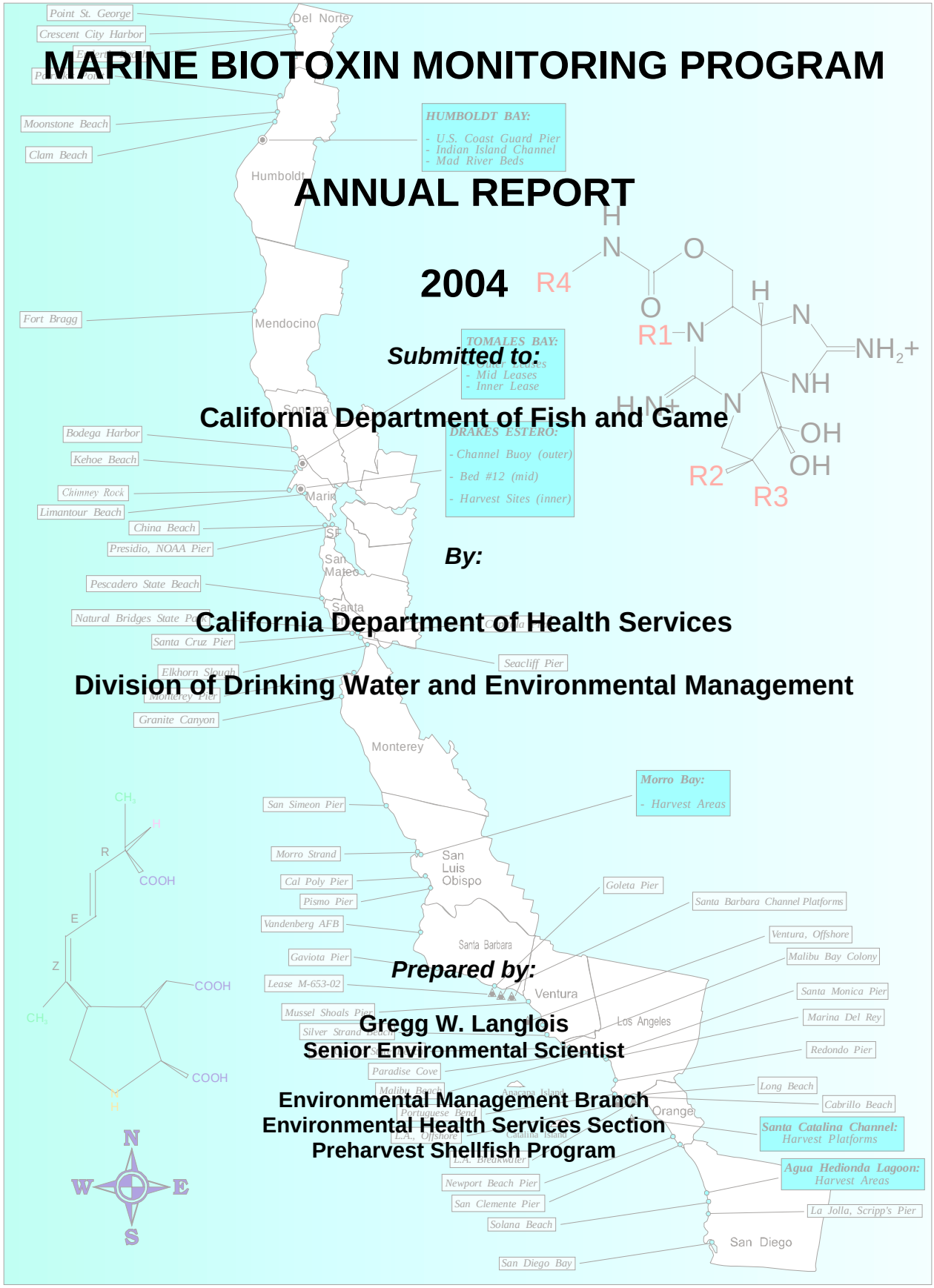
California Department of Health Services

Division of Drinking Water and Environmental Management

Prepared by:

Gregg W. Langlois
Senior Environmental Scientist

Environmental Management Branch
Environmental Health Services Section
Preharvest Shellfish Program



ACKNOWLEDGEMENTS

This report was prepared for the California Department of Fish and Game under agreement number PO170005. The California Department of Health Services would like to thank the Department of Fish and Game for their support of the paralytic shellfish poisoning monitoring portion of the marine biotoxin program.

The Department of Health Services' 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 Department of Health Services' 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. We would like to express our appreciation to Dale Watson, the U.C. Sea Grant Extension office in Crescent City, and the Department of Fish and Game biologists in Eureka and Crescent City for their help in obtaining plankton and razor clam samples. Their combined efforts allowed the Department of Health Services to alert the public when domoic acid concentrations increased to dangerous levels.

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

TABLE OF CONTENTS

INTRODUCTION

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

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

Because PSP toxicity represents a serious ongoing public health threat that requires year-round attention, the California Department of Health Services (DHS) has implemented a prevention program that has traditionally been comprised of five basic elements: (1) a coastal shellfish monitoring program; (2) monitoring of commercial shellfish product; (3) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); (4) mandatory reporting of disease cases; and (5) public information and education activities. In response to the occurrence of a new toxin, domoic acid, in the fall of 1991, DHS added a sixth element to the Marine Biotoxin Monitoring Program: phytoplankton monitoring. This latter monitoring effort was the first volunteer-based phytoplankton monitoring program in the U.S. This annual report describes the shellfish sampling element of the program for PSP toxins and domoic acid and the phytoplankton monitoring results during 2004. A summary is also provided for quarantine and health advisory activities.

Paralytic Shellfish Poisoning

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

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

The type and severity of symptoms depends on the amount of toxic shellfish consumed as well as the specific toxicity of the shellfish. Price et al. (1991) summarize the range of toxin dose responses as follows: 200 to 500 micrograms (µg) 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 per 100 grams (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, DHS began a volunteer-based phytoplankton monitoring program in 1993. 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 DHS has been able to detect and track numerous harmful algal blooms, improving the capabilities for protecting public health.

2004 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 98 different sites along the coast of California in 2004 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1153 shellfish samples collected statewide for PSP toxin assay during 2004. The greatest number of samples (381) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 96% of the samples collected in this county. The majority of these (247) were contributed by Johnson Oyster Company in Drakes Estero, which samples four stations on at least a weekly basis. The large proportion of Marin

County sites is a reflection of both the number of commercial growers and the frequency of occurrence of PSP toxicity in this region.

Commercial shellfish growers accounted for 61% of all samples collected in 2004, followed by coastal county health departments and various state agencies (10% and 21%, respectively; Table 2). Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2004, which equaled the increased effort of 2003 (Table 3). As mentioned above, monitoring of the outer coast is a key element in California's marine biotoxin monitoring program because all toxic blooms to date have originated offshore or along the coast. Monitoring coastal shellfish resources can therefore provide an early warning of toxic conditions that may soon impact shellfish in bays and estuaries, which harbor the majority of commercial shellfish growers and recreational clam beds.

The majority of samples collected in 2004 consisted of mussels (70%), followed by cultured pacific oysters (27%; Table 4). A variety of other species of shellfish were sampled for PSP toxin analysis in 2004, including rock scallops (*Crassadoma gigantea*), Washington clams (*Saxidomus nuttalli*), and Pismo clams (*Tivela stultorum*). The Marine Biotoxin Monitoring Program continues to use mussels as a primary indicator species for PSP toxins because of their ability to bioaccumulate these toxins at a faster rate that other bivalve species (Shumway, 1990). Differential uptake in mussels versus oysters during a major PSP event in 1991 was previously documented (California Department of Health Services, 1991).

Domoic Acid

There were 234 shellfish samples analyzed for domoic acid during 2004 compared to 208 samples analyzed the previous year (Table 5). Samples from 54 different sampling sites, representing all but one coastal county, were targeted for analysis as a result of observations from the volunteer monitoring network of high numbers of *Pseudo-nitzschia spp*. The greatest number of samples was submitted from San Luis Obispo County (54), Santa Barbara County (45), and Humboldt County (35).

Phytoplankton

There were 1195 phytoplankton samples collected during 2004 at 94 sampling sites representing all coastal counties (Table 6). The greatest numbers of samples were collected in Marin (238), San Luis Obispo (193), Los Angeles (169), and Santa Barbara (145) counties. Samples were collected at 108 different sampling sites throughout these counties by 60 volunteers (Figures 1c and 1d). Several areas (e.g., commercial shellfish growing areas) had multiple sites that are not individually identified in the figure and some volunteers may sample sites in multiple counties.

Of the 1195 phytoplankton samples collected in 2004, 854 (71%) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 78 different sampling sites throughout all 15 coastal counties in 2004. The greatest number of

samples containing toxin-producing species was collected in San Luis Obispo County (185), followed by Marin (139), Santa Barbara (119) and Los Angeles (91).

2004 RESULTS

Paralytic Shellfish Poisoning: Toxicity and *Alexandrium* Observations

The geographic distribution of PSP toxicity in 2004 was slightly greater than observed in 2003, however the magnitude of toxicity was approximately the same (Figure 2). Measurable concentrations of PSP toxins were found in 220 shellfish samples from the following coastal counties: Del Norte, Humboldt, Mendocino, Marin, San Francisco, San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Los Angeles, and San Diego. PSP toxin concentrations at or above the alert level of 80 micrograms (µg) per 100 grams of shellfish meat were detected in 24 of the 220 positive samples (11%) from three counties: Marin (12), Santa Cruz (5), and San Luis Obispo (7). PSP toxicity was found most frequently, and at the highest concentrations, along the coast of Marin County during 2004. The highest concentration detected was 1602 µg in mussels from a Drakes Estero sentinel mussel station.

In general, the temporal distribution of PSP toxins in 2004 was typical of the average annual pattern observed over the past 23 years (Figure 3). There was a brief early spring increase in *Alexandrium* (Figure 4), with PSP toxins in shellfish increasing above the alert level by the last week of March in San Luis Obispo. Toxin levels decreased quickly and remained low or absent until the end of June throughout the state. The midsummer increase in PSP toxins began in late June and continued through the end of July, extending from Marin through San Luis Obispo counties. An unusual winter event resulted in dangerous levels of the PSP toxins in mussels along the San Luis Obispo coast in December.

Following is an overview of *Alexandrium* and PSP toxin monitoring efforts during 2004. Detailed maps illustrating the weekly relative PSP toxin concentrations for each month, the monthly distribution and relative abundance of *Alexandrium* and *Pseudo-nitzschia*, and the monthly lists of program participants are provided in separate monthly reports. These reports are available at the following Internet site:

http://www.dhs.ca.gov/ps/ddwem/environmental/Shellfish/Shellfish.htm

Alexandrium was observed as early as January at sites in Marin and San Mateo counties. Low levels of PSP toxins were detected in mussel samples from Marin and Santa Cruz counties at this time. Low concentrations of these toxins were detected throughout most of the month in Drakes Estero (Marin County) and during the first three weeks of January at the Santa Cruz Pier. Toxin concentrations did not exceed 54 µg/100g of shellfish tissue.

The distribution of *Alexandrium* increased significantly in March at some Southern California sites, increasing in numbers along the coast of San Luis Obispo and Santa

Barbara, including three offshore sites in this region. In addition, *Alexandrium* was observed throughout most of the month near Catalina Island and throughout the month offshore of Palos Verdes (Los Angeles County). Low numbers of this toxin-producing dinoflagellate were also observed at the beginning of March near Carlsbad and later in the month at Scripps Pier in La Jolla (San Diego County).

Coinciding with this noticeable increase in *Alexandrium*, high concentrations of PSP toxins were detected in mussels from the sentinel station at the Cal Poly Pier in Avila on March 24 (535 µg) and March 31 (217 µg). On March 26 the San Luis Obispo County Public Health Department issued a health advisory advising sport harvesters to avoid consuming any bivalve shellfish in the county. By April 14 the concentration of PSP toxins at this site had decreased to 48 µg. Lower concentrations of PSP toxins were also detected in shellfish samples from Morro Bay, Pismo Pier, and below Pt. Conception at Gaviota Pier during March. Increasing levels of these toxins were detected in oysters from an offshore aquaculture lease in Santa Barbara, rising from 51 µg (March 17) to 77 µg (March 22).

Alexandrium distribution declined at most sites from April through June, with low numbers of this dinoflagellate occurring at different sites during this time. Low levels of PSP toxins were also occasionally detected.

Alexandrium distribution in Southern California increased slightly in June at sites in San Luis Obispo and Santa Barbara counties. *Alexandrium* was also observed in samples collected offshore of the Palos Verdes peninsula (Los Angeles County) and Catalina Island. Mussels collected on June 29 from Avila (San Luis Obispo County) contained 79 µg of PSP toxins. *Alexandrium* distribution increased along the entire Northern California coastline in June (Figure 2). The greatest increase in relative abundance of this dinoflagellate was observed along the Marin coast towards the end of June. Low levels of PSP toxins detected in sentinel mussels inside Humboldt Bay at the end of May continued throughout June. Low levels of these toxins were also detected at other sites along the northern Humboldt coast and farther south at sites in Marin, San Francisco, San Mateo, Santa Cruz, and Monterey counties. Elevated levels of PSP toxins were detected in shellfish from sites in Marin (129 µg) and Santa Cruz (81 µg) during the last week in June.

By July the distribution of *Alexandrium* increased along most of the California coastline. In Northern California the greatest numbers of this dinoflagellate were observed by mid month at several Santa Cruz sites in northern Monterey Bay. An additional increase appeared to occur at the end of the month in Santa Cruz Harbor and in Monterey at the commercial pier. The elevated level of PSP toxins detected in shellfish from Marin County in June increased through July 7. Mussels from the Drakes Estero sentinel buoy contained 1602 µg of PSP toxins at this time. Toxin levels declined throughout the rest of the month but remained above the alert level until July 22. Sentinel mussels from Santa Cruz Pier had also increased above the alert level in late June and continued to increase through the second week of July (141 µg). Toxin levels appeared to decline then increase again between July 21 (68 µg) and July 28 (770 µg). By August 11 the

toxin level had decreased to 49 µg and was not detectable by the following week.

Alexandrium was also observed along the entire Southern California coast in July. Small numbers of this dinoflagellate species were observed at sites in Santa Barbara and Los Angeles counties. *Alexandrium* was also observed in samples collected offshore near Catalina Island. The distribution of this dinoflagellate increased significantly at sites in San Luis Obispo County, where it was observed throughout the month. Coinciding with the increase in *Alexandrium* at San Luis Obispo sites, the concentration of PSP toxins increased at several locations in this region. Mussels from Morro Bay increased in PSP toxicity, reaching 203 µg on July 11. By July 19 the level of toxins had decreased to 70 µg, remaining at this level through July 24. Toxin concentrations continued to decreased through August.

Alexandrium was observed along most of the Northern and Central California coastline in October. There was a significant increase in the relative abundance of this dinoflagellate at several locations between Marin and San Luis Obispo counties. PSP toxins were detected at several locations throughout this region in October. Low levels of PSP toxins were detected in Drakes Estero during the last week of September and persisted through October. By the third week of the month the concentration of toxin had increased above the alert level, but declined to safe levels by the following week.

Program participants' samples continued to contain cells of *Alexandrium* at a number of Northern and Central California sites in November and December. Low levels of PSP toxins were also detected during this time. The numbers of this dinoflagellate increased along the San Luis Obispo coast in November and December. By December the highest relative abundance of this dinoflagellate was observed inside Morro Bay and farther south at Avila. Sampling and field observations conducted by the Morro Bay National Estuary Program (MBNEP) caught a sudden increase in *Alexandrium* at Cayucos Pier, just north of Morro Bay. Subsequent mussel sampling by the MBNEP volunteers revealed that PSP toxin concentrations had increased significantly during the first week of the month, reaching 248 µg by December 8. Toxin levels then declined but remained above the alert level through December 22. As a result of the MBNEP's observations and increased sampling effort DHS was able to issue a health advisory for the region, alerting the public to refrain from consuming sport harvested mussels. In addition to this episode, low levels of PSP toxins were detected inside Morro Bay throughout the month.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

Measurable concentrations of domoic acid were found in 144 samples from the following coastal counties: Del Norte, Humboldt, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, and San Diego. Concentrations of domoic acid above the alert level (20 micrograms (µg) per gram of shellfish meat, or 20 parts per million (ppm)) were detected in 24 of the 144 positive samples from the following five counties: Del Norte, Humboldt, Santa Cruz, San Luis Obispo, and Santa Barbara. The highest concentration of domoic acid (170 ppm) was detected in a sample

of razor clams from Humboldt County.

The magnitude of domoic acid toxicity in 2004 was similar to that detected in 2003, although the geographic range was slightly greater in 2004. The temporal distribution of *Pseudo-nitzschia*, and the resultant accumulation of domoic acid in shellfish, followed the same seasonal pattern as in 2002 and 2003. Domoic acid concentrations increased in early March and persisted through May and into June in some areas (Figure 5). This same pattern was apparent for observations of *Pseudo-nitzschia* in phytoplankton samples. The percent composition of this diatom was high at several sites as early as January and February (Figure 6), however the cell mass was quite low. Under these circumstances the percent composition data alone can be misleading. To adjust for the importance of cell mass, as well as sampling effort, a Relative Abundance Index (RAI) was formulated. The RAI is based on an estimate of cell mass as determined by settled cell volume (a), the percent composition of each species (b), and the sampling effort as determined by the total tow length (c):

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

The RAI data can provide perspective on the significance of the percent composition data for *Pseudo-nitzschia* or other species of interest. Many of the observations of high percent compositions of *Pseudo-nitzschia* in January and February (Figure 6) have less importance when the RAI is determined (Figure 7).

By February the relative abundance of *Pseudo-nitzschia* increased slightly at sites along the San Luis Obispo and Santa Barbara coastline and increased dramatically at sites from Los Angeles through San Diego counties. The majority of shellfish samples analyzed in February did not contain a detectable level of domoic acid, however. A low concentration (5.8 ppm) of domoic acid was detected in a shellfish sample from Scripps Pier (San Diego County) on February 25.

Pseudo-nitzschia percentages fluctuated in March. Numbers of this diatom increased inside Morro Bay in mid-March, while decreasing offshore of Diablo Cove and at the Cal Poly Pier in Avila. Domoic acid was detected at a high concentration (45 ppm) in mussels from Pismo Pier thanks to the extra effort of researchers at U.C. Santa Barbara (Figure 3). A low concentration (6 ppm) of domoic acid was detected in a mussel sample from Goleta Pier (Santa Barbara County) on March 31.

The relative abundance of *Pseudo-nitzschia* increased at most locations along the California coast in April. U.C. Santa Cruz researchers reported bloom levels of this diatom at the Santa Cruz Wharf on April 8. This diatom was also observed in high densities at Seacliff Pier (April 14) and Capitola Pier (April 22). Despite the detection of high numbers of *Pseudo-nitzschia* at the Santa Cruz Wharf in early April, domoic acid was not detected in mussels from this site until April 21 (19 ppm). In contrast, the first detection of elevated numbers of this diatom at Capitola Pier was associated with a high toxin concentration (26 ppm). Increasing numbers of this diatom were observed in Humboldt Bay by the end of the month. Domoic acid was not detected in sentinel

mussel samples from this region.

The relative abundance of *Pseudo-nitzschia* also increased significantly at most sites along the Southern California coast in April. The low levels of domoic acid detected in Santa Barbara County at the end of March continued to increase in April. Toxin levels peaked by the third week of the month, reaching 87 ppm and 26 ppm in mussels and oysters, respectively, from an offshore aquaculture lease. Mussels from Goleta Pier also contained 20 ppm of domoic acid at this time. By April 12 this toxin was detected in low levels in mussels and razor clams collected by the Department of Fish and Game (DFG) at several sites in San Luis Obispo County. Razor clams in Morro Bay reached 41 ppm by April 14. Farther south along the Ventura coast domoic acid concentrations reached 15 ppm in a mussel sample collected on April 13. In addition, a sample of Pismo clams collected by volunteer Bill Weinerth on April 28 contained 10 ppm of this toxin. Low levels of domoic acid were also detected by mid-month farther south along the Los Angeles coast. Mussels collected at Malibu Beach on April 14 contained 3.7 ppm of domoic acid. By the end of the month this toxin was also detected at a low concentration in mussels from offshore of Orange County (4 ppm on April 28).

The high relative abundance of *Pseudo-nitzschia* continued through the beginning of May, declining to very low levels in most areas by mid-month. Elevated levels of domoic acid continued to be detected at sites in Santa Barbara County at the beginning of May. Mussels from an offshore oil platform contained 27 ppm of domoic acid and oysters from an aquaculture lease less than one mile offshore contained 23 ppm of this toxin. Lower levels of this toxin were also detected in mussels onshore at Goleta Pier and further downcoast at sites in Ventura and Los Angeles counties.

Increasing numbers of *Pseudo-nitzschia* were observed in Humboldt Bay towards the latter part of May. A low level of domoic acid (8 ppm) was detected in mussels from Point St. George (Del Norte County) on May 19 and the toxin level in razor clams from just north of this site exceeded the alert level, reaching 33 ppm on May 20. A low concentration of domoic acid (4 ppm) was also detected in sentinel mussels from Humboldt Bay on May 18. By June the greatest relative abundances of this diatom were observed at Crescent City (Del Norte County) and, to a lesser extent, inside Humboldt Bay. These high densities decreased throughout the month.

The elevated level of domoic acid detected in razor clams from Del Norte County in May continued to increase in June. Clams dug on June 5 contained toxin concentrations ranging from 43 ppm to 83 ppm. Razor clams collected from Clam Beach (Humboldt County) had very high concentrations of domoic acid, ranging from 120 ppm to 170 ppm. Several samples of cleaned (eviscerated) razor clams from this site were donated for testing. The resulting concentrations of domoic acid in the meat ranged from 130 ppm to 170 ppm. A razor clam sample collected from this site during the last week of June contained 78 ppm of domoic acid. The latter result was still well above the alert level of 20 ppm but indicative of a possible downward trend that was consistent with the phytoplankton observations for this region. Elevated levels of domoic acid continued into July in razor clams from Del Norte County. Three clam samples dug on July 2

contained widely varying concentrations of domoic acid: 11 ppm, 26 ppm, and 54 ppm. The latter sample was of cleaned (eviscerated) razor clams. We would like to express our appreciation to Dale Watson, the U.C. Sea Grant Extension office in Crescent City, and the Department of Fish and Game biologists in Eureka and Crescent City for their help in obtaining plankton and razor clam samples. Their efforts allowed DHS to track this bloom and alert the public to the dangers associated with this event.

The relative abundance of *Pseudo-nitzschia* at north coast sites decreased through August, then increased dramatically in September. Unfortunately tide conditions did not allow further sampling of razor clams to determine if this event caused a further increase in domoic acid concentrations. The high relative abundance of this diatom persisted in Crescent City through November. Lower but significant numbers of this diatom were also observed inside Humboldt Bay during this period. A low concentration of domoic acid (1.7 ppm) was detected in sentinel mussels inside Humboldt Bay during the first week of November.

2004 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

On March 26, San Luis Obispo County issued a warning against human consumption of sport-harvested bivalve (two-shelled) shellfish from its coastal waters after elevated levels of PSP were detected in mussels. This action was based on samples collected and analyzed by the Department of Health Services Marine Biotoxin Monitoring Program.

The annual quarantine on sport-harvested mussels taken from the ocean waters of California for human consumption began early in 2004. Routine monitoring detected elevated levels of domoic acid in mussels from Santa Cruz and Santa Barbara counties, resulting in the implementation of the annual quarantine on April 23 instead of the usual start date of May 1.

On April 30 the State Health Director warned consumers not to eat sport-harvested species of bivalve shellfish, sardines and anchovies, or the organs, or viscera, of sport-harvested or commercially sold lobster and crab taken from the coast of Los Angeles, Orange and Ventura counties. This warning was based on the detection of dangerous levels of domoic acid in the viscera of anchovies from these counties.

On May 7 the State Health Director warned consumers to avoid eating sport-harvested species of sardines and anchovies or the viscera, or internal organs, of crab and lobster from Monterey Bay in Monterey and Santa Cruz counties. This warning was based on the detection of elevated levels of domoic acid in sardines and anchovies caught from Monterey Bay.

On June 10 the State Public Health Officer warned consumers not to eat sport-harvested bivalve (two-shelled) shellfish from Humboldt and Del Norte counties because of possible domoic acid contamination. Elevated levels of this toxin were detected in razor clams in these areas.

The annual mussel quarantine on the sportharvesting of mussels was rescinded on schedule at midnight on October 31. This action did not affect the status of other existing health advisories.

Finally, on December 17, consumers were warned by the State Public Health Officer not to eat sport-harvested mussels from San Luis Obispo County due to the detection of high levels of the PSP toxins in mussels from this region.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2004.

REFERENCES

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

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

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

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

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

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

TABLES 1 – 8

Table 1. Total number of shellfish samples collected per coastal county in 2004 for PSP assay.

COUNTY	# SAMPLES
Del Norte	21
Humboldt	115
Mendocino	4
Sonoma	3
Marin	381
San Francisco	11
San Mateo	20
Santa Cruz	79
Monterey	12
San Luis Obispo	168
Santa Barbara	128
Ventura	10
Los Angeles	60
Orange	24
San Diego	117
TOTAL	**1153**

Table 2. Number of shellfish samples collected by program participants, per coastal county, in 2004 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	13	7	--	1	21
Humboldt	104	5	6	--	--	115
Mendocino	--	4	--	--	--	4
Sonoma	--	--	2	--	1	3
Marin	368	--	10	--	3	381
San Francisco	--	10	--	--	1	11
San Mateo	--	20	--	--	--	20
Santa Cruz	--	28	51	--	--	79
Monterey	--	--	7	--	5	12
San Luis Obispo	105	--	59	--	4	168
Santa Barbara	69	--	51	7	1	128
Ventura	--	9	--	--	1	10
Los Angeles	--	23	5	--	32	60
Orange	17	3	--	--	4	24
San Diego	45	--	49	14	9	117
TOTAL =	**708**	**115**	**240**	**21**	**62**	**1153**

Table 3. Program participants by county that submitted shellfish samples in 2004 for PSP assay.

COUNTY	AGENCY
Del Norte	Del Norte County Health Department
	U.C. Sea Grant Extension
	California Department of Fish and Game
	DHS Volunteer
Humboldt	Humboldt County Environmental Health Department
	Coast Seafoods Company
	California Department of Fish and Game
Mendocino	Mendocino County Environmental Health Department
Sonoma	DHS Volunteer
	DHS Marine Biotoxin Monitoring Program
Marin	Johnson Oyster Company
	Cove Mussel Company
	Hog Island Oyster Company
	Marin Oyster Company
	DHS Volunteer
	DHS Marine Biotoxin Monitoring Program
San Francisco	San Francisco County Health Department
	DHS Volunteer
San Mateo	San Mateo County Environmental Health Department
Santa Cruz	Santa Cruz County Environmental Health Department
	University of California Santa Cruz
Monterey	Monterey Abalone Company
	California Department of Fish and Game
San Luis Obispo	Williams Shellfish Company
	University of California Santa Barbara Marine Science Institute
	California Department of Fish and Game
	DHS Volunteer
	Morro Bay National Estuary Program
	Morro Bay Harbor District
Santa Barbara	University of California Santa Barbara Marine Science Institute
	California Department of Parks and Recreation
	Vandenberg Air Force Base, Environmental Health Services

	Santa Barbara Mariculture Company
	DHS Volunteer
Ventura	Ventura County Environmental Health Department
	DHS Volunteer
Los Angeles	Los Angeles County Health Department
	Aquarium of the Pacific Long Beach
	Los Angeles Regional Water Quality Control Board
Orange	Orange County Health Care Agency
	Ecomar, Inc.
	DHS Volunteer
San Diego	Carlsbad Aquafarm, Inc.
	DHS Volunteer
	Scripps Institute of Oceanography
	U.S. Navy

Table 4. Number and species of samples collected in 2004 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels[1]:	
Sentinel	177
Wild	60
Cultured	92
Total Bay Mussels	***329***
Sea Mussels[2]:	
Sentinel	214
Wild	238
Total Sea Mussels	***452***
Mixed Bay and Sea Mussels	25
Total Mussels	**806**
Pacific Oysters[3]	
Cultured	**315**
Rock Scallops	**7**
Other[4]	**25**
TOTAL	**1153**

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

Table 5. Total number of shellfish samples analyzed for domoic acid, per coastal county, in 2004.

COUNTY	# SAMPLES
Del Norte	15
Humboldt	35
Mendocino	3
Sonoma	1
Marin	2
San Francisco	1
San Mateo	0
Santa Cruz	16
Monterey	7
San Luis Obispo	54
Santa Barbara	45
Ventura	6
Los Angeles	17
Orange	6
San Diego	26
TOTAL	**234**

Table 6. Total number of phytoplankton samples collected per coastal county in 2004.

COUNTY	# SAMPLES
Del Norte	25
Humboldt	57
Mendocino	2
Sonoma	14
Marin	238
Contra Costa	7
San Francisco	40
San Mateo	31
Santa Cruz	83
Monterey	24
San Luis Obispo	193
Santa Barbara	145
Ventura	9
Los Angeles	169
Orange	49
San Diego	109
TOTAL	**1195**

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2004.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
01/05/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	41
01/07/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	48
01/07/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	41
01/12/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	48
01/12/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	43
01/12/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	45
01/14/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	49
01/18/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	43
01/19/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
01/19/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
01/21/04	Santa Cruz	Sea Mussel, wild	Natural Bridges	48
01/21/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	54
01/21/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	40
01/26/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	43
01/27/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	43
FEBRUARY				
02/04/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	43
02/11/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	47
02/16/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	41
02/16/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay	42
02/18/04	Santa Cruz	Sea Mussel, wild	Natural Bridges	40
02/21/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay	40
02/21/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	45
MARCH				
03/01/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
03/17/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	51
03/20/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	46

03/20/04	Santa Barbara	Bay Mussel, wild	Gaviota Pier	46
03/22/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	77
03/23/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	43
03/24/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	535
03/31/04	San Luis Obispo	Sea Mussel, wild	Pismo Pier	48
03/31/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Avila Pier	217
03/31/04	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	47
APRIL				
04/01/04	San Luis Obispo	Sea Mussel, wild	Morro Bay, WQ Station #04	42
04/06/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	214
04/13/04	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	43
04/13/04	Los Angeles	Sea Mussel, wild	Portuguese Bend	39
04/14/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	48
04/19/04	San Diego	Sea Mussel, wild	San Diego Bay, U.S. Navy Pier	45
04/20/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	46
04/27/04	Los Angeles	Sea Mussel, wild	Redondo Beach Pier	42
04/28/04	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	61
MAY				
05/03/04	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., Plt Houchin	39
05/06/04	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	49
05/18/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	44
05/18/04	Los Angeles	Rock Scallop, wild	Long Beach Breakwater	45
05/25/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	41
05/26/04	Santa Barbara	Mixed Sea/Bay Mussels	Santa Barbara Ch., Plt. Holly	39
JUNE				
06/01/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
06/02/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
06/03/04	Humboldt	Sea Mussel, wild	Patrick's Point	43
06/04/04	Humboldt	Sea Mussel, wild	Moonstone Beach, Humboldt	43
06/07/04	San Francisco	Sea Mussel, wild	China Beach	43
06/08/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	42
06/08/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	55

06/14/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	50
06/16/04	San Mateo	Sea Mussel, wild	Pescadero State Beach	45
06/16/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	47
06/17/04	Monterey	Bay Mussel, wild	* Not Reported *	38
06/17/04	Monterey	Sea Mussel, wild	* Not Reported *	42
06/17/04	Monterey	Bay Mussel, wild	Elkhorn Slough, Highway Bridge	38
06/21/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	39
06/21/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	59
06/21/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	43
06/21/04	San Francisco	Sea Mussel, wild	China Beach	41
06/22/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	41
06/22/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	49
06/23/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	38
06/23/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	53
06/23/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	62
06/23/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	74
06/24/04	Monterey	Bay Mussel, wild	Monterey Pier	50
06/25/04	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock, N.	40
06/27/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
06/29/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	53
06/29/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	57
06/29/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	79
06/30/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	62
06/30/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #34	46
06/30/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	129
06/30/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	81
JULY				
07/01/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #11	50
07/01/04	San Mateo	Sea Mussel, wild	Pescadero State Beach	51
07/02/04	Del Norte	Sea Mussel, wild	Point St. George	43
07/02/04	Marin	Sea Mussel, wild	Drakes Bay	41
07/04/04	Monterey	Bay Mussel, wild	Monterey Bay, Commercial Wharf	47

07/05/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	51
07/05/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	71
07/05/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	205
07/05/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	43
07/06/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	44
07/06/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	45
07/06/04	Mendocino	Sea Mussel, wild	Fort Bragg	55
07/06/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	68
07/07/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
07/07/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	420
07/07/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #4	68
07/07/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	1602
07/07/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	86
07/11/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	100
07/11/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	861
07/11/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #8	62
07/11/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	660
07/11/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	40
07/11/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #13	203
07/13/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	44
07/13/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	48
07/14/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	53
07/14/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	163
07/14/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	222
07/14/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	141
07/18/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	114
07/18/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
07/19/04	Del Norte	Sea Mussel, wild	Point St. George	53
07/19/04	Mendocino	Sea Mussel, wild	Fort Bragg	47
07/19/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	45
07/19/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #13	70
07/20/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43

07/21/04	San Francisco	Sea Mussel, wild	China Beach	44
07/21/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	68
07/22/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	51
07/22/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	49
07/24/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #13	71
07/26/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	37
07/26/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	39
07/26/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	47
07/27/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	39
07/27/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	48
07/28/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	770
07/29/04	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	54
07/29/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	45
AUGUST				
08/01/04	Del Norte	Sea Mussel, wild	Point St. George	47
08/02/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	38
08/02/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	48
08/02/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	49
08/03/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	45
08/03/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	47
08/03/04	Mendocino	Sea Mussel, wild	Fort Bragg	43
08/04/04	San Mateo	Sea Mussel, wild	Pescadero State Beach	41
08/04/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	367
08/09/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	42
08/09/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
08/09/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	43
08/10/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43
08/11/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	49
08/15/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	43
08/16/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	41
08/17/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
08/22/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	45

08/23/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	43
08/23/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	48
08/23/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
08/27/04	Santa Barbara	Sea Mussel, wild	Santa Barbara, VAFB Boat Dock	43
08/30/04	Del Norte	Sea Mussel, wild	Point St. George	42
08/30/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	50
08/30/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	51
08/30/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	44
SEPTEMBER				
09/05/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	48
09/08/04	Santa Barbara	Sea Mussel, wild	Santa Barbara, VAFB Boat Dock	43
09/20/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
09/22/04	Santa Barbara	Sea Mussel, wild	Santa Barbara, VAFB Boat Dock	38
09/23/04	Santa Barbara	Rock Scallop viscera	Santa Barbara Ch., Plt. Holly	73
09/27/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
09/28/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	39
OCTOBER				
10/03/04	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	41
10/04/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
10/04/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
10/05/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
10/06/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	37
10/06/04	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	42
10/06/04	Santa Barbara	Sea Mussel, wild	Goleta Pier	37
10/11/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	36
10/11/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	37
10/13/04	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	36
10/18/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #11	49
10/18/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	58
10/18/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	95
10/18/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	99
10/18/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	48

10/20/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	41
10/20/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	73
10/20/04	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #17	36
10/20/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	74
10/21/04	Santa Barbara	Sea Mussel, wild	Santa Barbara, VAFB Boat Dock	36
10/22/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	45
10/25/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	58
10/25/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
10/27/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40
10/28/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	44
10/28/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	48
10/31/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	39
NOVEMBER				
11/02/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
11/03/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	41
11/06/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	40
11/08/04	Marin	Sea Mussel, wild	Drakes Bay, Chimney Rock LBS	36
11/08/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	37
11/08/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
11/10/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	35
11/12/04	San Mateo	Sea Mussel, wild	Pescadero State Beach	37
11/13/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #11A	35
11/13/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #11A	52
11/16/04	Santa Cruz	Sea Mussel, wild	Natural Bridges	35
11/17/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #11A	44
11/27/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	56
DECEMBER				
12/05/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #11A	44
12/06/04	San Luis Obispo	Bay Mussel, Sentinel	Cayucos Pier	119
12/08/04	San Luis Obispo	Sea Mussel, wild	Cayucos Pier	248
12/11/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #11A	37
12/11/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #11A	48

12/13/04	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	35
12/14/04	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	37
12/15/04	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
12/18/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	45
12/18/04	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #11A	35
12/21/04	Marin	Sea Mussel, Sentinel	Drakes Bay, Chimney Rock LBS	37
12/21/04	San Luis Obispo	Sea Mussel, wild	Cayucos Pier	94
12/27/04	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay	42

Table 8. Date and location of shellfish samples containing detectable levels of domoic acid during 2004.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	DA (ppm)
FEBRUARY				
02/25/04	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	5.8
MARCH				
03/07/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	1.5
03/31/04	San Luis Obispo	Sea Mussel, wild	Pismo Pier	45
03/31/04	Santa Barbara	Sea Mussel, wild	Goleta Pier	6.1
APRIL				
04/01/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	3.7
04/12/04	Santa Cruz	Sea Mussel, wild	Santa Cruz, Capitola Pier	26
04/12/04	Santa Cruz	Sea Mussel, wild	Santa Cruz, Seacliff Pier	11
04/12/04	San Luis Obispo	Clam, razor	Morro Bay	3.1
04/12/04	San Luis Obispo	Clam, razor	Morro Bay	4
04/12/04	San Luis Obispo	Sea Mussel, wild	Morro Strand, Motel Pt.	1.4
04/13/04	Santa Barbara	Sea Mussel, wild	Goleta Pier	12
04/13/04	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	15
04/14/04	San Luis Obispo	Clam, razor	Morro Bay	41
04/14/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	15
04/14/04	Los Angeles	Sea Mussel, wild	Malibu Beach	3.7
04/17/04	Santa Barbara	Sea Mussel, wild	Gaviota Pier	8.9
04/19/04	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., M-653-02	8.6
04/21/04	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	19
04/21/04	Santa Barbara	Sea Mussel, Sentinel	Goleta Pier	20
04/21/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	26
04/21/04	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., M-653-02	87
04/22/04	Santa Cruz	Sea Mussel, wild	Santa Cruz, Capitola Pier	13
04/22/04	Santa Cruz	Sea Mussel, wild	Santa Cruz, Seacliff Pier	5.5
04/23/04	Santa Cruz	Sea Mussel, wild	Natural Bridges	8
04/27/04	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	1.8

04/28/04	Santa Barbara	Sea Mussel, Sentinel	Goleta Pier	11
04/28/04	Ventura	Pismo Clam	Ventura, Silverstrand Beach	9.8
04/28/04	Orange	Bay Mussel, wild	Santa Catalina Ch., Plt. Eva	4
04/29/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	6.5
MAY				
05/03/04	Santa Barbara	Sea Mussel, wild	Santa Barbara Ch., Plt Houchin	27
05/04/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	18
05/04/04	Santa Barbara	Bay Mussel, Sentinel	Santa Barbara Ch., M-653-02	23
05/04/04	Los Angeles	Sea Mussel, wild	Portuguese Bend	1.7
05/06/04	Santa Barbara	Sea Mussel, wild	Goleta Pier	5.9
05/11/04	Ventura	Sea Mussel, wild	Ventura, Malibu Bay Colony	2.1
05/17/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	9.6
05/18/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	3.8
05/19/04	Del Norte	Sea Mussel, wild	Point St. George	8.2
05/19/04	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	13
05/20/04	Del Norte	Clam, razor	Crescent City Harbor	33
JUNE				
06/04/04	Humboldt	Razor Clam, muscle	Humboldt, Clam Beach	130
06/04/04	Humboldt	Razor Clam, muscle	Humboldt, Clam Beach	150
06/04/04	Humboldt	Razor Clam, muscle	Humboldt, Clam Beach	160
06/04/04	Humboldt	Razor Clam, muscle	Humboldt, Clam Beach	170
06/05/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	43
06/05/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	51
06/05/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	83
06/05/04	Humboldt	Clam, razor	Humboldt, Clam Beach	120
06/30/04	Humboldt	Clam, razor	Humboldt, Clam Beach	78
JULY				
07/02/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	11
07/02/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	13
07/02/04	Del Norte	Clam, razor	Crescent City, Endert's Beach	26
07/02/04	Del Norte	Razor Clam, muscle	Crescent City, Endert's Beach	54

AUGUST				
08/01/04	Humboldt	Clam, razor	Humboldt, Moonstone Beach	16
NOVEMBER				
11/02/04	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	1.7

FIGURES 1 – 13.

Figure 1a. Locations of shellfish sampling stations during 2004 (Del Norte to Monterey counties).

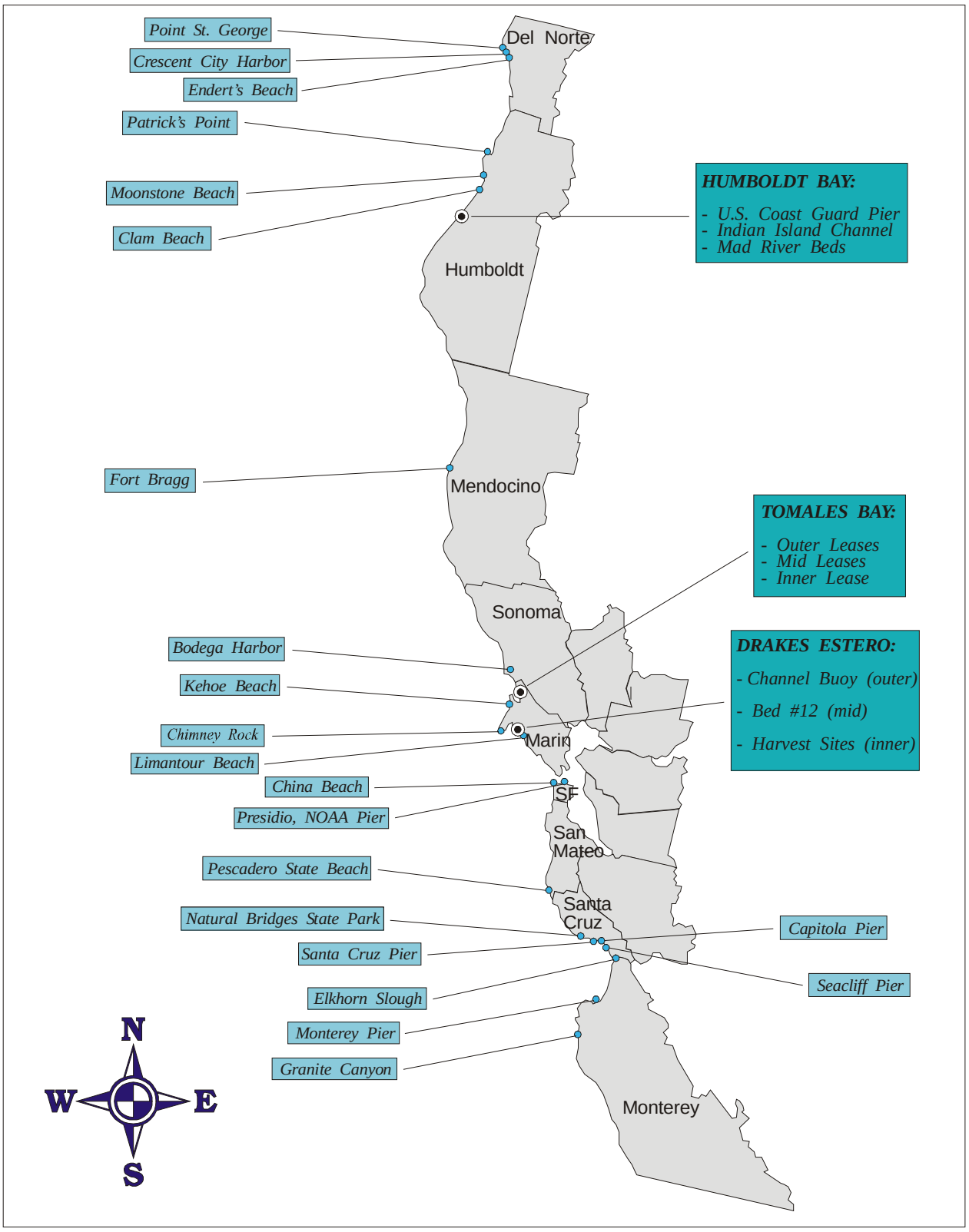


Figure 1b. Locations of shellfish sampling stations during 2004 (San Luis Obispo to San Diego counties).

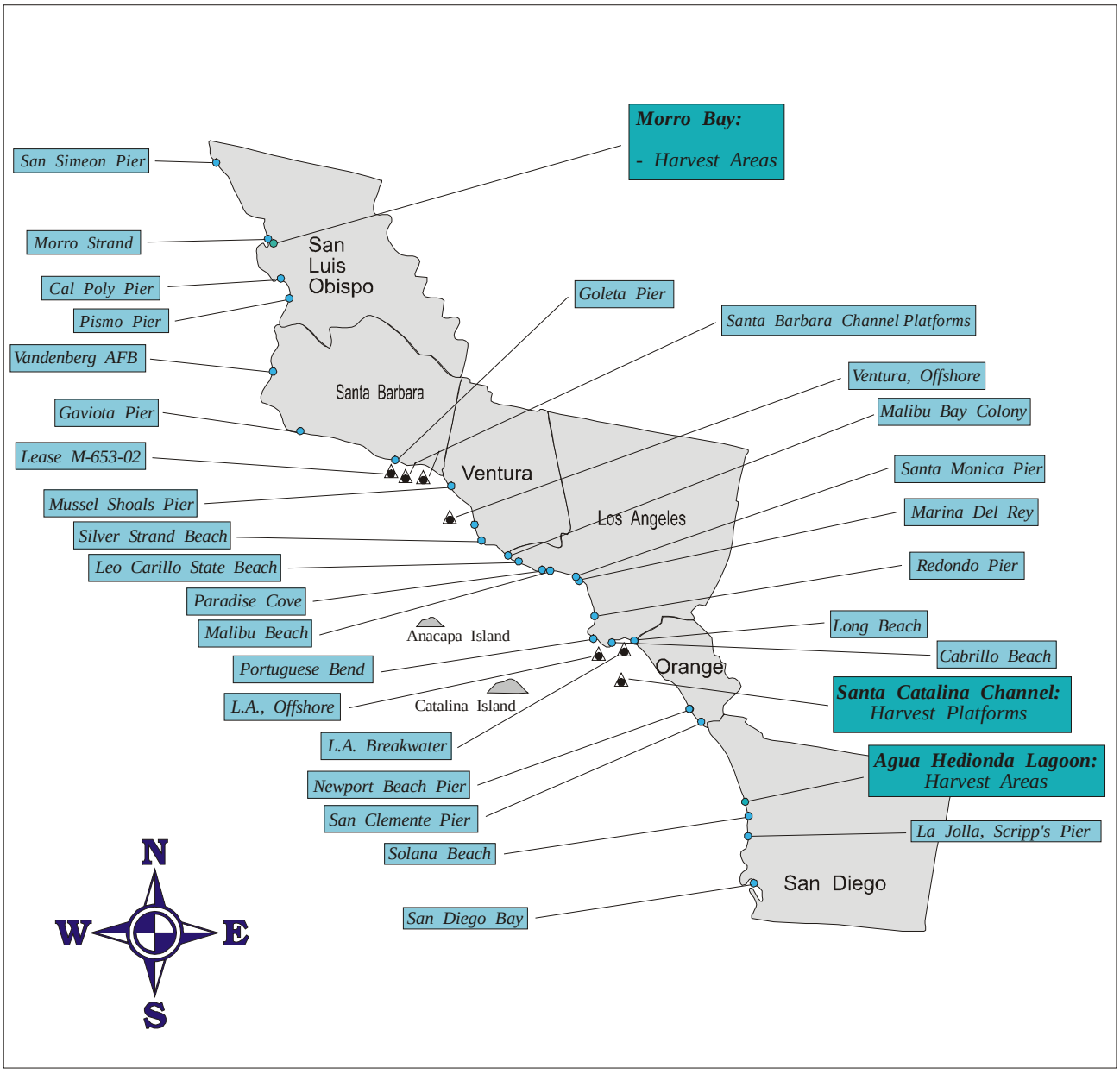


Figure 1c. Locations of phytoplankton sampling stations during 2004 (Del Norte to Monterey counties).

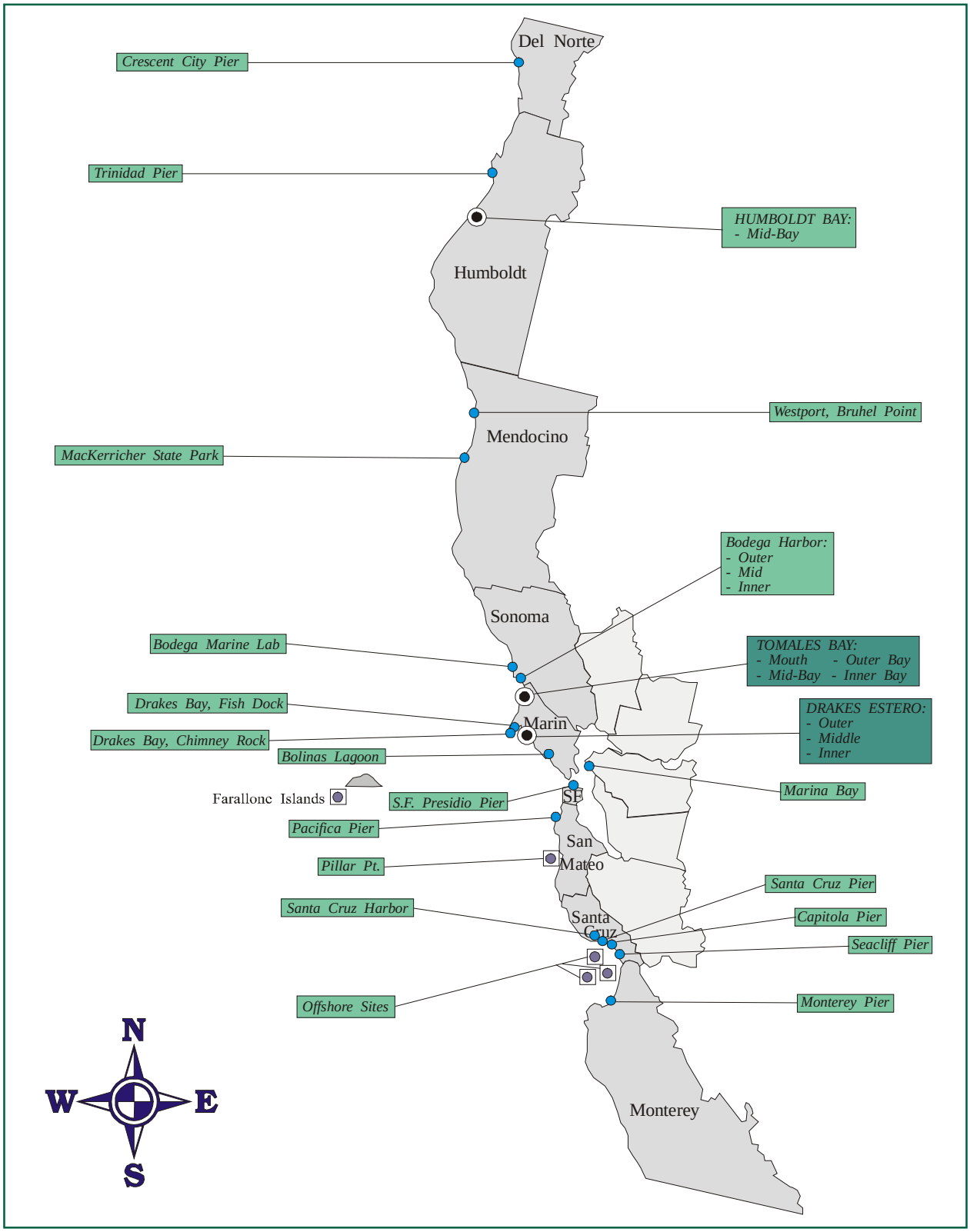


Figure 1d. Locations of phytoplankton sampling stations during 2004 (San Luis Obispo to San Diego counties).

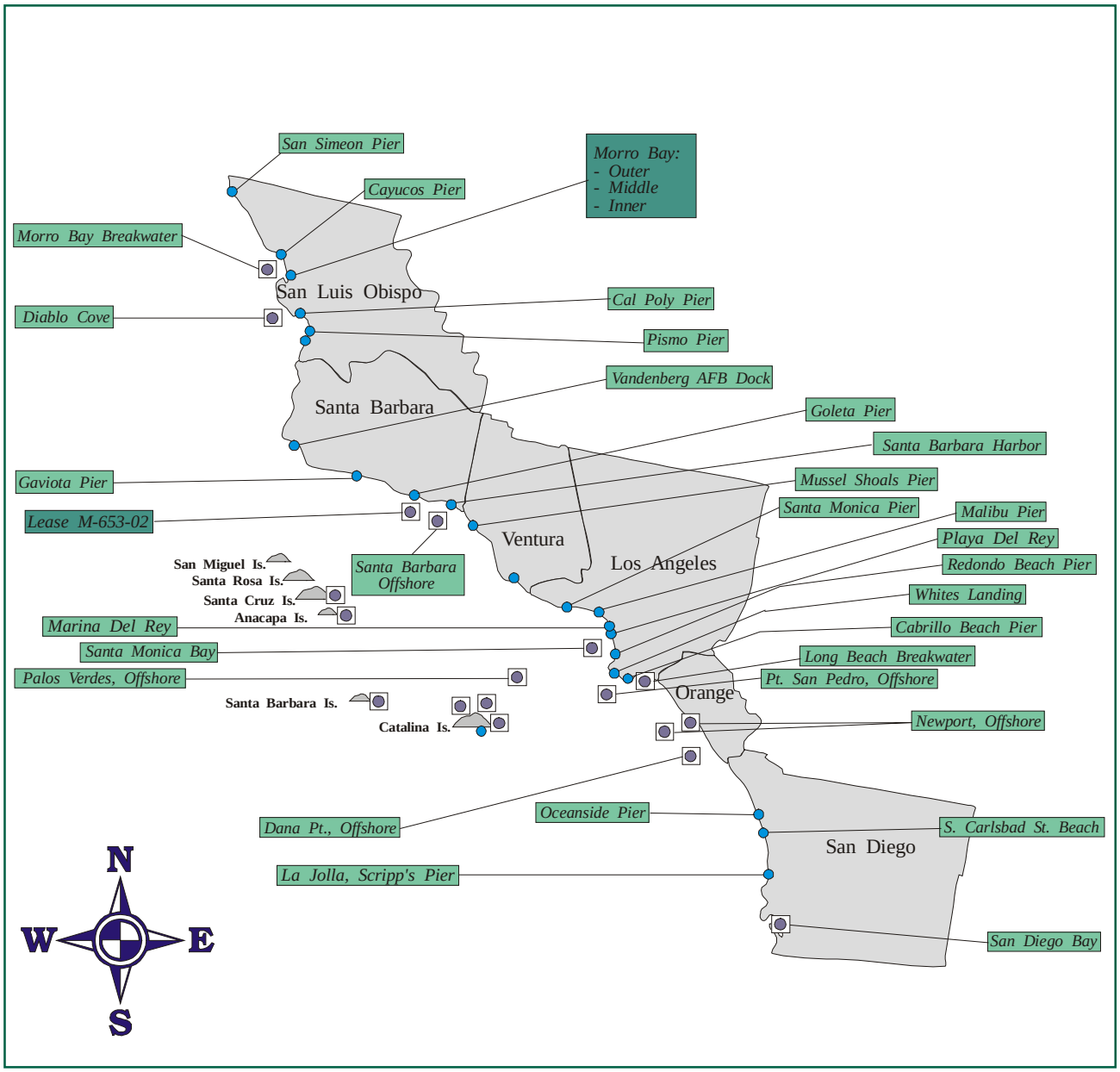


Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2004.

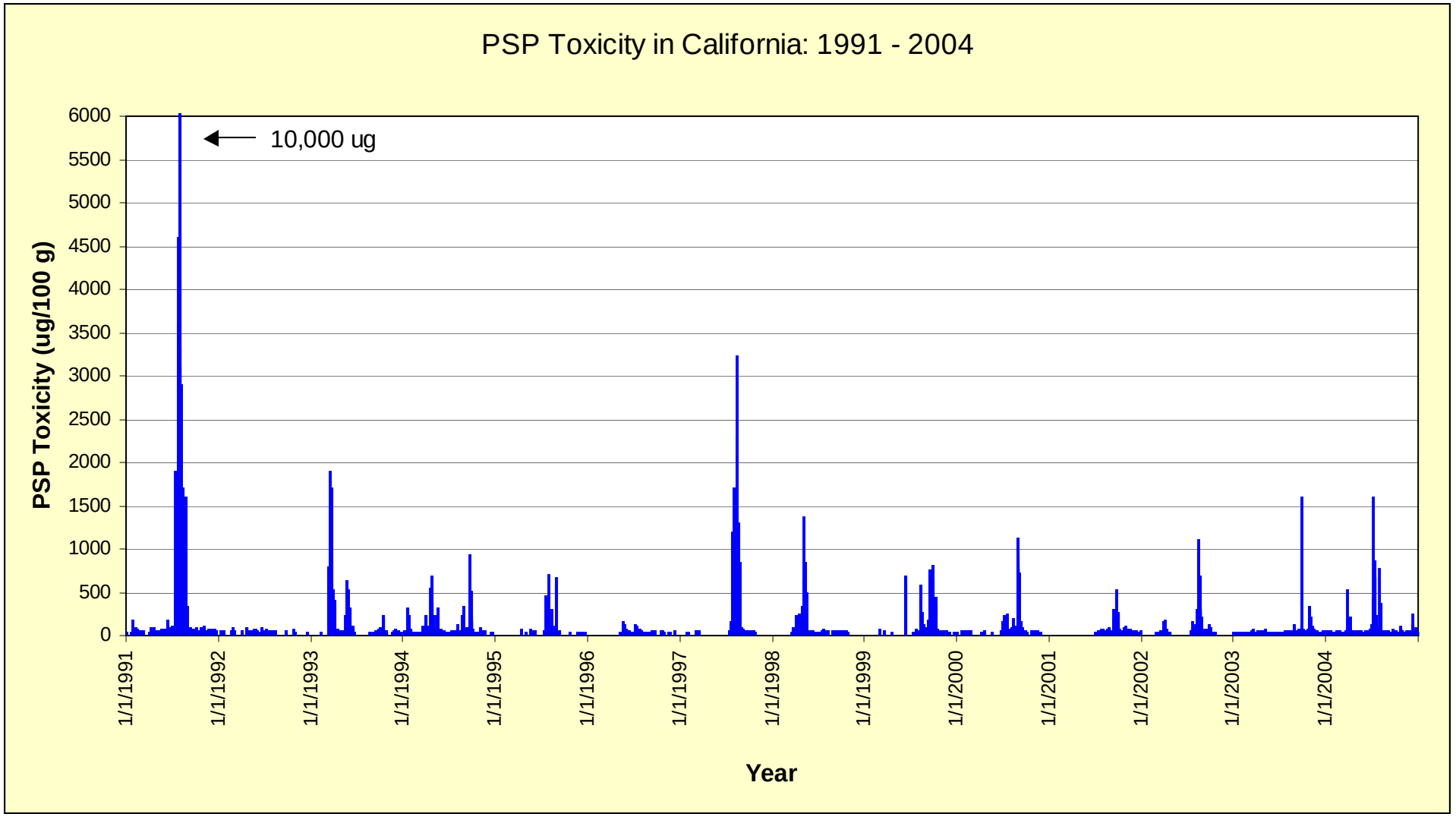


Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2004.

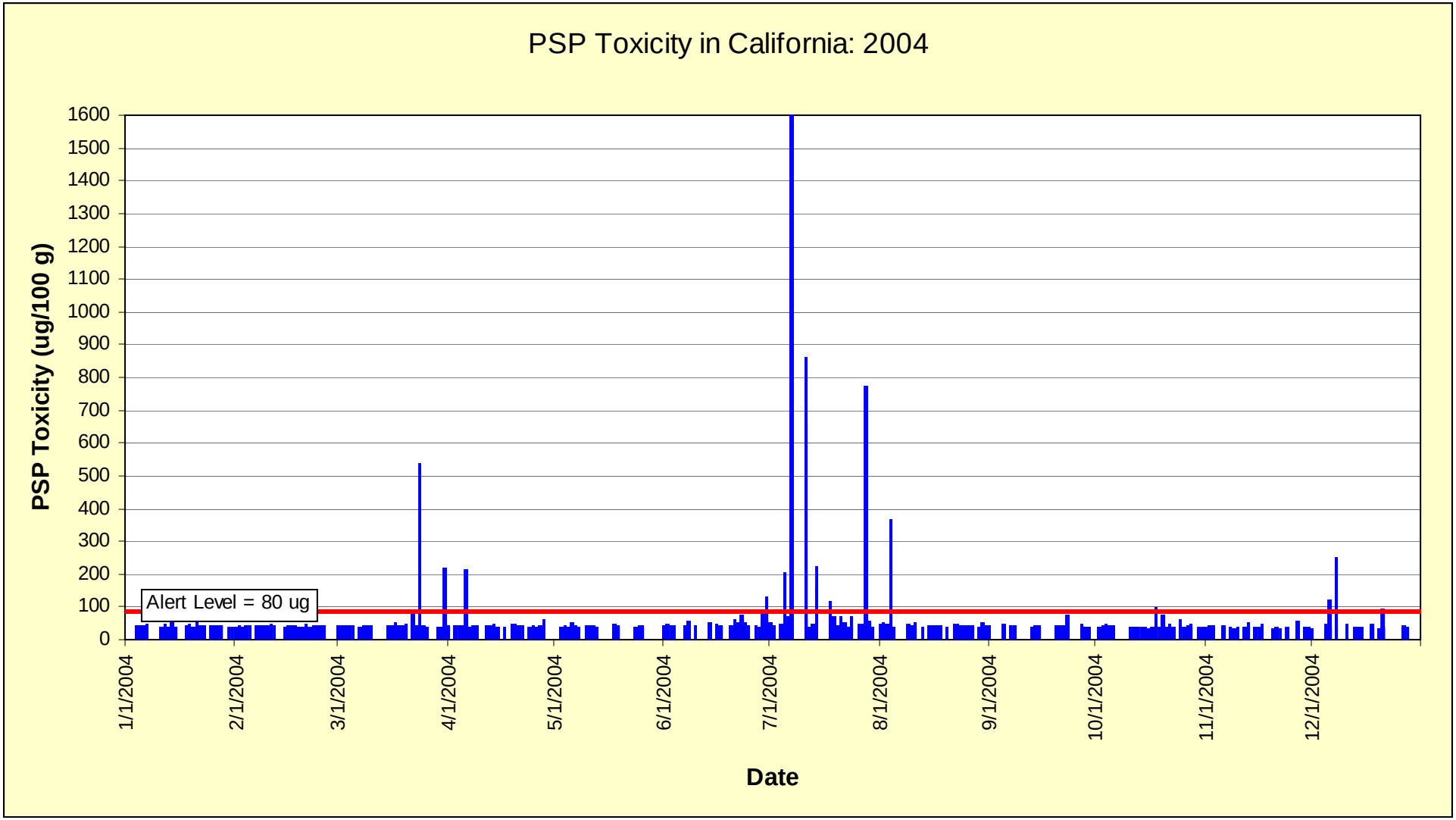


Figure 4. Temporal distribution and percent composition of *Alexandrium spp*.

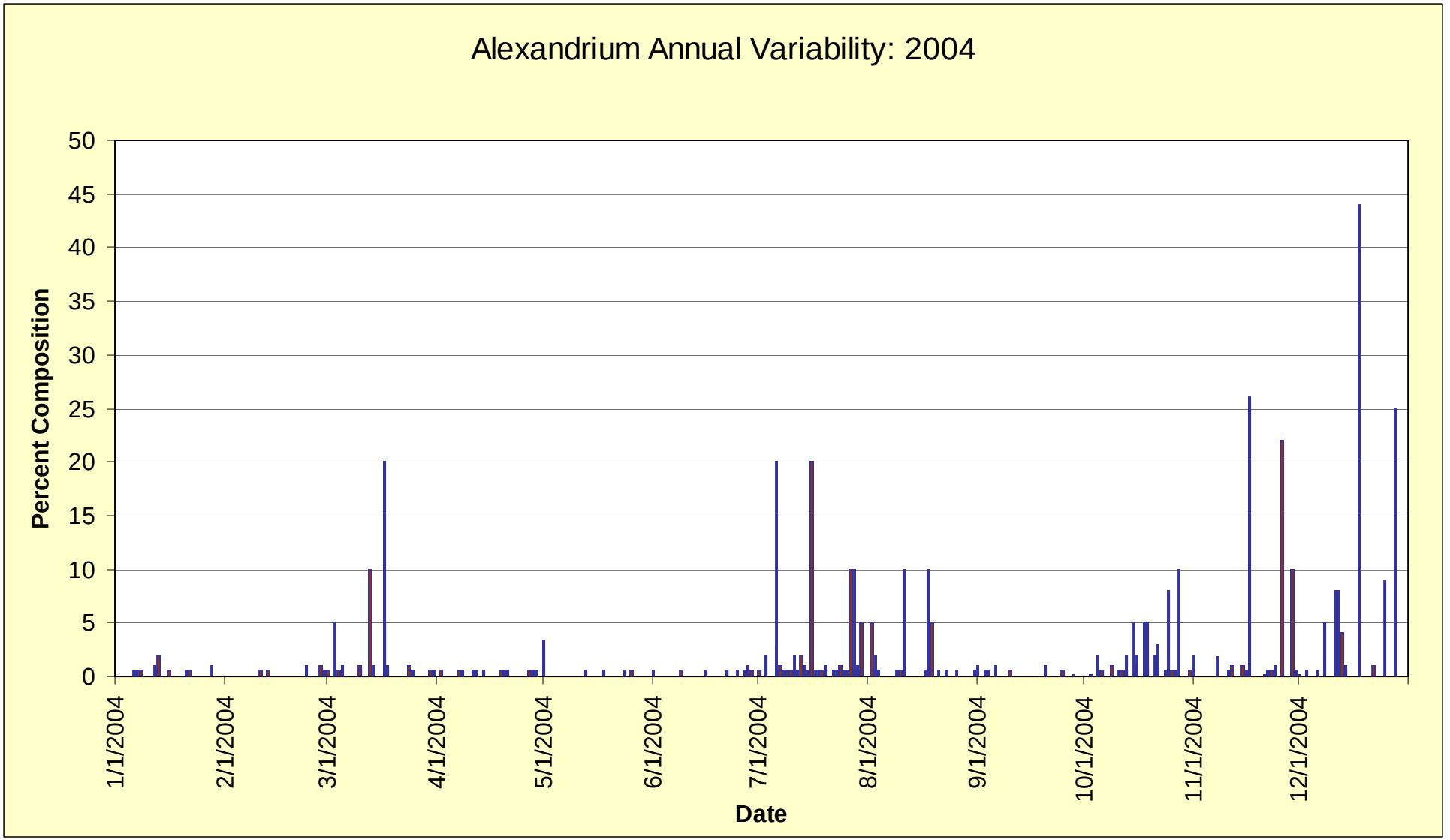


Figure 5. Domoic acid concentration and temporal distribution in California shellfish during 2004.

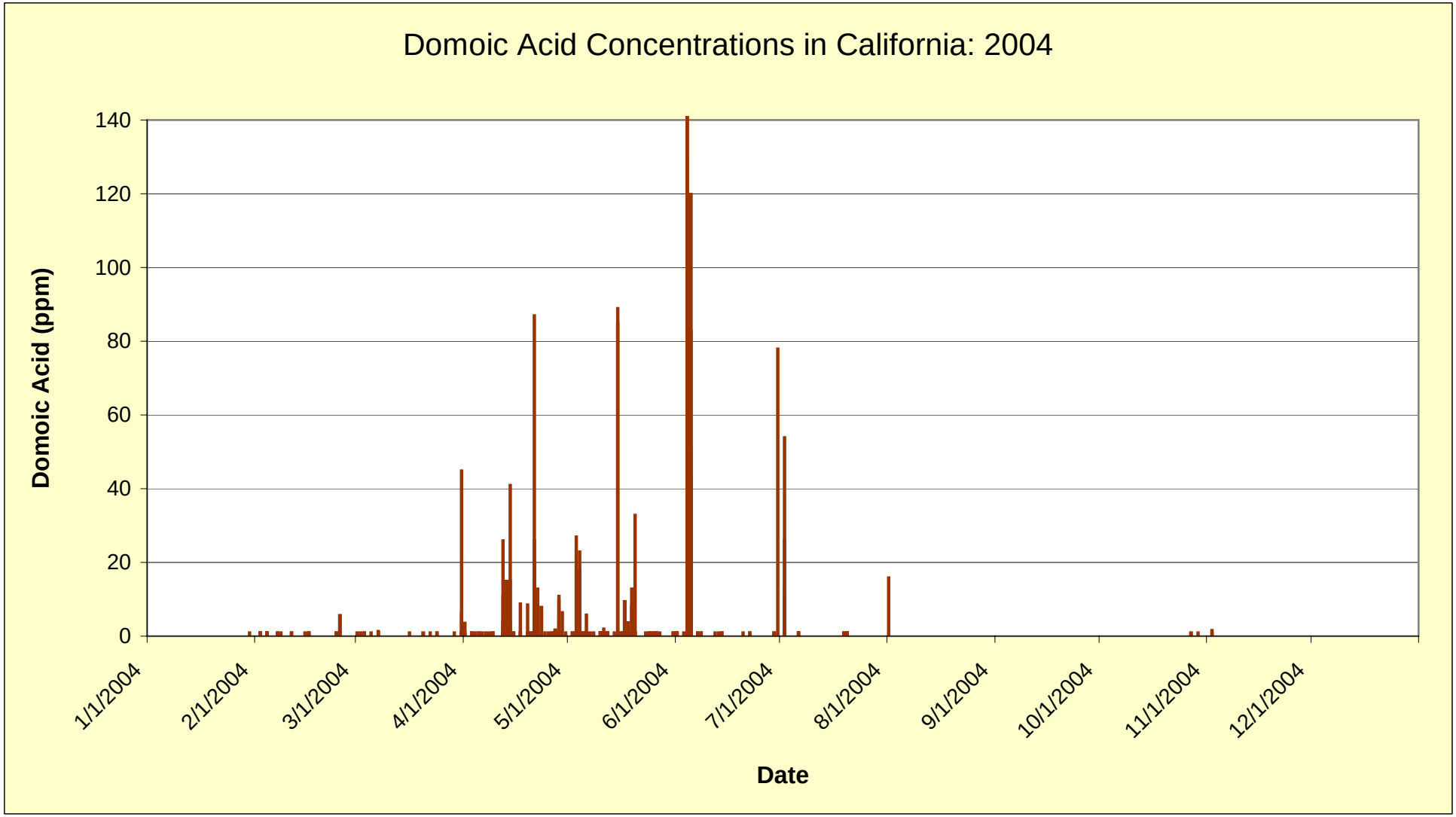


Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia spp*.

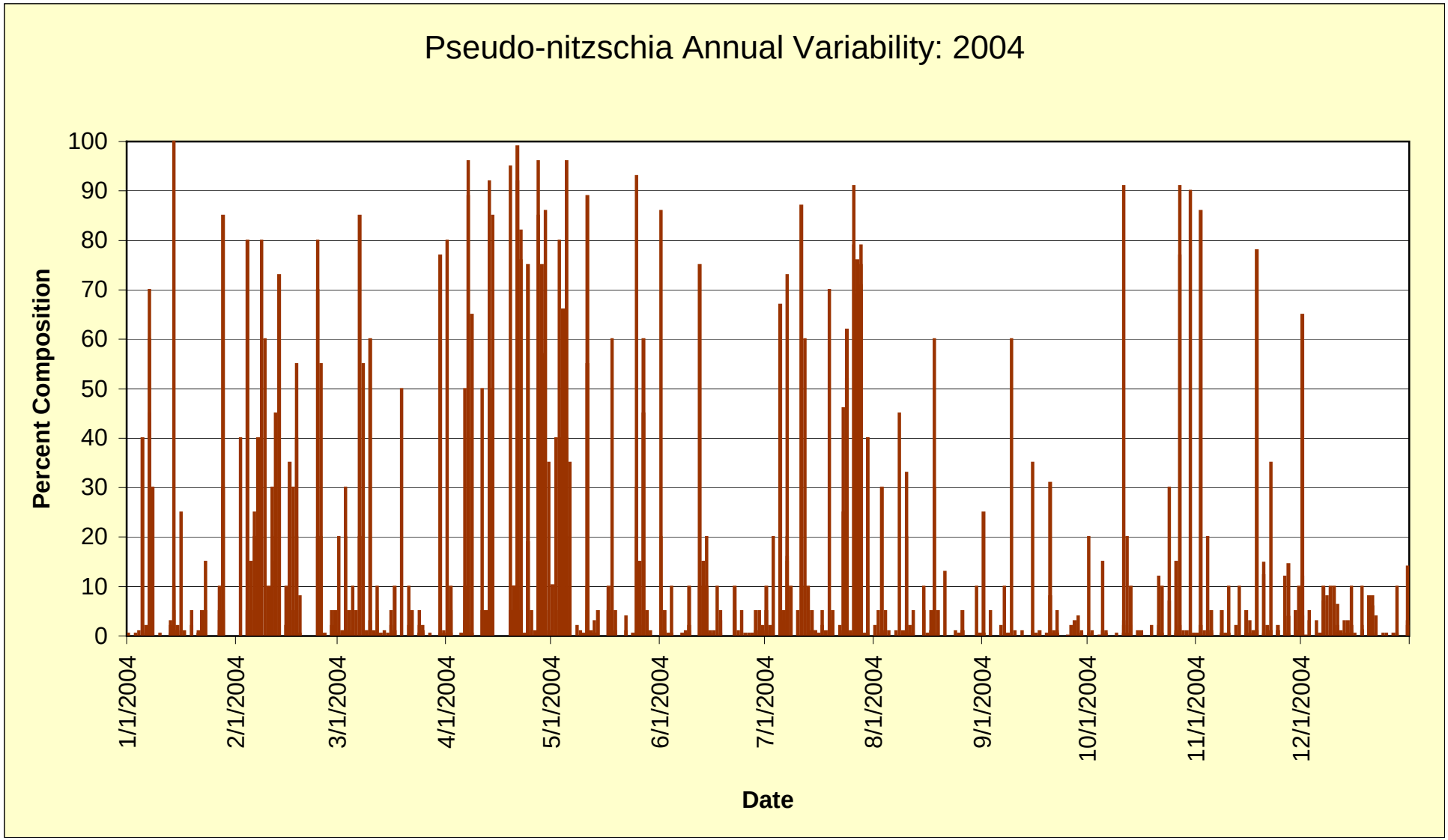


Figure 7. Temporal distribution and relative abundance of *Pseudo-nitzschia spp*.