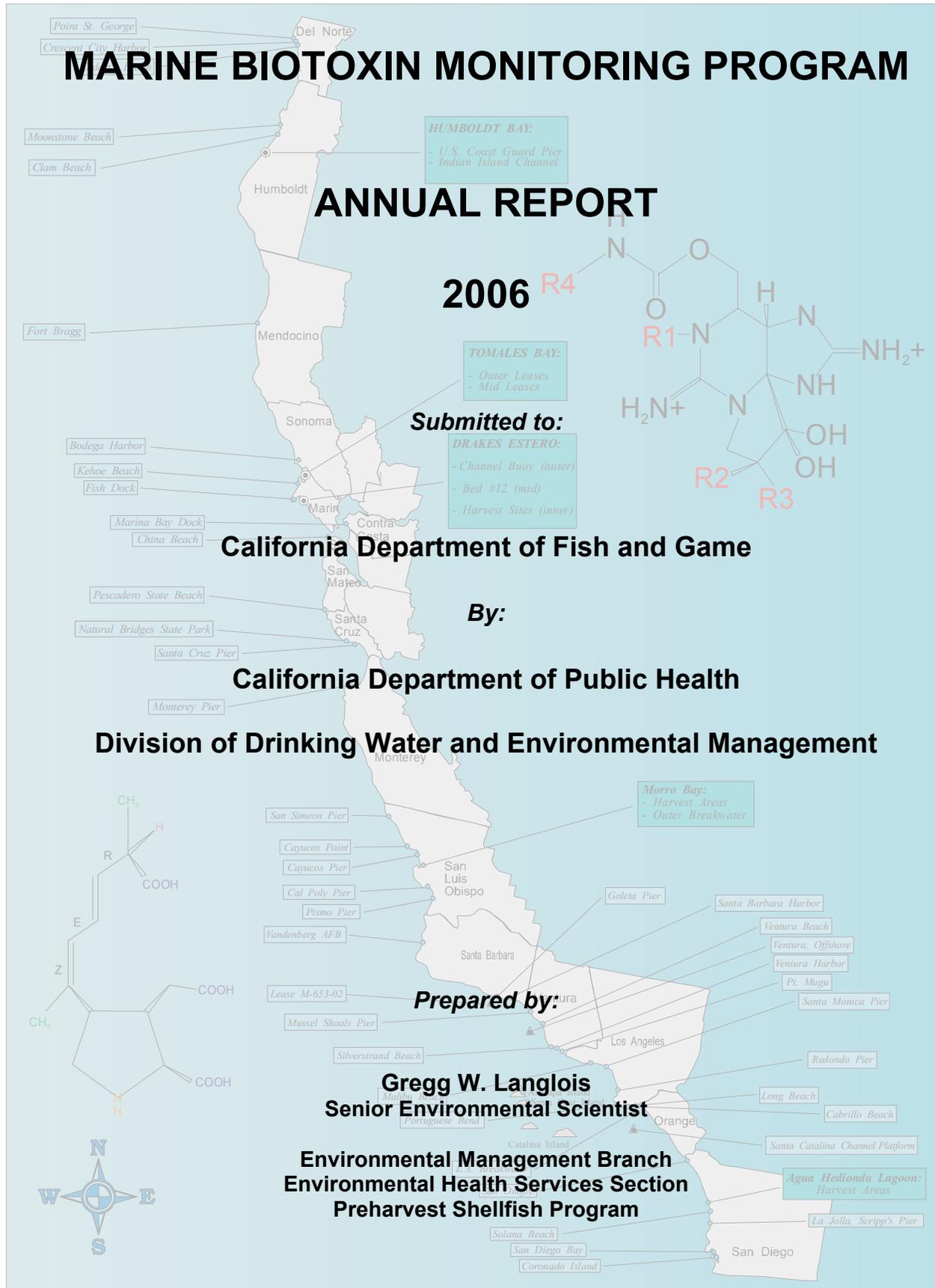
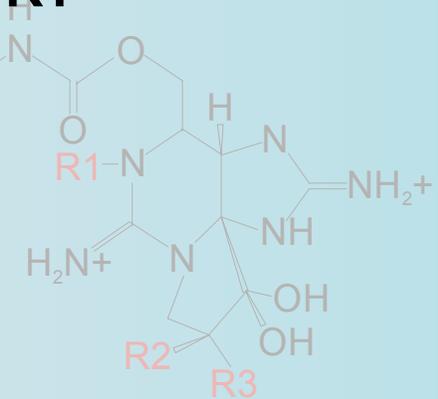


MARINE BIOTOXIN MONITORING PROGRAM

ANNUAL REPORT

2006



Submitted to:

- DRAKES ESTERO:**
- Channel Buoy (outer)
 - Bed #12 (mid)
 - Harvest Sites (inner)

California Department of Fish and Game

By:

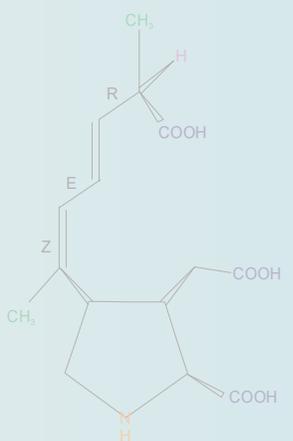
California Department of Public Health

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ACKNOWLEDGEMENTS

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

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

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

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INTRODUCTION

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

In the fall of 1991 another natural toxin was identified along the California coastline. Domoic acid, a neurotoxin of lower potency than the PSP toxins, has become of 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 Public Health (CDPH) has implemented a prevention program that has traditionally been comprised of five basic elements: (1) a coastal shellfish monitoring program; (2) monitoring of commercial shellfish product; (3) an annual statewide quarantine on sport-harvested mussels (from May 1 through October 31); (4) mandatory reporting of disease cases; and (5) public information and education activities. In response to the occurrence of a new toxin, domoic acid, in the fall of 1991, CDPH added a sixth element to the Marine Biotoxin Monitoring Program: phytoplankton monitoring. This 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 2006. A summary is also provided for quarantine and health advisory activities.

Paralytic Shellfish Poisoning

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

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

The type and severity of symptoms depends on the amount of toxic shellfish consumed as well as the specific toxicity of the shellfish. Price et al. (1991) summarize the range of toxin dose responses as follows: 200 to 500 micrograms (μg) per 100 grams (g) of shellfish tissue will cause at least minor symptoms, 500 to 2000 μg will cause moderate to severe symptoms, and toxin concentrations greater than 2000 μg will produce serious to lethal effects. It should be noted that exceptions exist and serious health effects have also been documented at much lower concentrations (100 to 400 μg). The federal alert level for PSP toxicity is 80 $\mu\text{g}/100$ g of shellfish tissue, and the detection limit for the PSP bioassay is approximately 40 $\mu\text{g}/100$ 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 $\mu\text{g/g}$ may result in mild to moderate symptoms (gastrointestinal), 40 to 700 $\mu\text{g/g}$ may result in moderate to severe neurologic symptoms, and domoic acid concentrations greater than 450 $\mu\text{g/g}$ may result in severe neurologic symptoms and/or death.

Phytoplankton

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

2006 SAMPLING EFFORT

Paralytic Shellfish Poisoning

Shellfish samples were collected at 74 different sites along the coast of California in 2006 (Figures 1a and 1b). Several commercial growing areas had multiple sites representing different harvest areas. There were 1129 shellfish samples collected statewide for PSP toxin assay during 2006. The greatest number of samples (378) was collected at sites in Marin County (Table 1), with commercial shellfish aquaculture companies providing approximately 91% of the samples collected in this county. The majority of these (234) were contributed by Johnson Oyster Company and Drakes Bay

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

Commercial shellfish growers accounted for 68% of all samples collected in 2006, followed by various state agencies and coastal county health departments (17% and 7%, respectively; Table 2). Several other program participants, including federal agencies and volunteers, provided valuable assistance by contributing their sampling effort in 2006. The diversity of participants is a valuable component of the monitoring program (Table 3). As mentioned above, monitoring of the outer coast is a key element in California's marine biotoxin monitoring program because all toxic blooms to date have originated offshore or along the coast. Monitoring coastal shellfish resources can therefore provide an early warning of toxic conditions that may soon impact shellfish in bays and estuaries, which harbor the majority of commercial shellfish growers and recreational clam beds.

The majority of samples collected in 2006 consisted of mussels (67%), followed by cultured pacific oysters (30%; Table 4). A variety of other species of shellfish were sampled for PSP toxin analysis in 2006, including rock scallops (*Crassadoma gigantea*), and several genera of clams. The Marine Biotoxin Monitoring Program continues to use mussels as a primary indicator species for PSP toxins because of their ability to bioaccumulate these toxins at a faster rate than other bivalve species (Shumway, 1990). Differential uptake in mussels versus oysters during a major PSP event in 1991 was previously documented (California Department of Health Services, 1991).

Domoic Acid

There were 250 shellfish samples analyzed for domoic acid during 2006 compared to 181 samples analyzed the previous year (Table 5). Samples from 43 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 number of samples was submitted from San Luis Obispo County (52) and Santa Barbara County (44).

Phytoplankton

There were 1577 phytoplankton samples collected during 2006 at 137 sampling sites representing all coastal counties (Table 6). The greatest numbers of samples were collected in Marin (252), San Luis Obispo (247), Santa Barbara (216), and Los Angeles (185) counties. Samples were collected along all coastal counties by 78 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 1577 phytoplankton samples collected in 2006, 1062 (67%) contained at least one toxigenic species. Toxin-producing phytoplankton species were detected at 112

different sampling sites throughout all of the 15 coastal counties in 2006. The greatest number of samples containing toxin-producing species was collected in San Luis Obispo (211), Santa Barbara (168), Los Angeles (119), and Marin (111) counties.

2006 RESULTS

Paralytic Shellfish Poisoning Toxicity and *Alexandrium* Observations

The geographic distribution and magnitude of PSP toxicity in 2006 was slightly greater than observed in 2005 (Figure 2). There were more samples above the alert level that were distributed throughout a greater number of counties than occurred in 2005. Measurable concentrations of PSP toxins were found in 296 shellfish samples from the following coastal counties: Humboldt, Marin, San Mateo, Santa Cruz, Monterey, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Orange, and San Diego.

PSP toxin concentrations at or above the alert level were detected in 58 samples from Marin (6), Santa Cruz (6), Monterey (4), San Luis Obispo (25), Santa Barbara (11), Ventura (4), Los Angeles (1), and San Diego (1) counties. PSP toxicity was found most frequently along the coast of San Luis Obispo County during 2006. The highest single toxin concentration detected was 1312 µg/100 g of shellfish meat in rock scallop viscera from Monterey and 744 µg in mussels from Goleta Pier (Santa Barbara).

Alexandrium was present along the entire California coastline throughout 2006. Of special note are the significant relative abundances of this dinoflagellate that were observed along most of the Southern California coast from March through December. It is extremely rare for this dinoflagellate species to be present in this region, much less in persistently high numbers and for such an extended period of time. PSP toxins were present at low levels in shellfish samples every month during 2006. Alert levels of the PSP toxins were present every month during 2006 except June and December. The temporal distribution of PSP toxins was, in general, typical of the average annual pattern, with an early spring peak in activity (Figure 3). What was unusual about the increased toxicity detected in March through May is that it spanned the entire coastline between Marin and San Diego. Alert levels were detected throughout most of this range, including Los Angeles (306 µg on March 23) and San Diego (112 µg on March 13). The latter occurrences are significant because PSP toxins rarely exceed the alert level in Southern California counties. The last recorded sample from San Diego to exceed the alert level for PSP toxins was 26 years ago (March 19, 1985).

There was a separate PSP event that began in mid-September and continued through the end of December, with alert levels of the PSP toxins being detected through mid-November at sites in San Luis Obispo. Although the temporal distribution of PSP toxins in 2006 was similar to observed patterns over the past 25 years, there was a significant southward shift in toxicity.

Following is an overview of *Alexandrium* and PSP toxin monitoring efforts during 2006. 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.CDPH.ca.gov/ps/ddwem/environmental/Shellfish/default.htm>

In a pattern similar to that reported for 2005, there was an early winter increase in PSP toxins in Northern California. Phytoplankton samples collected in January contained small numbers of *Alexandrium* at several Northern California sites between Marin and Monterey. PSP toxins were first detected in mussels at a sentinel mussel station in outer Drakes Estero on January 24, and increased above the alert level by January 31 (93 µg). *Alexandrium* continued to be present at numerous sites between Marin and Santa Cruz counties in February and March. Toxin levels decreased below the alert level in Drakes Estero after the first week of February, then increased again during the last week of the month (167 µg, February 23). A low level of PSP toxins was also detected in mussels from Santa Cruz Pier on February 15. By the second week of the month toxin levels increased above the alert level in mussels from Santa Cruz Pier. The elevated levels of the PSP toxins detected in Drakes Estero continued through the first week of March, then declined to low or undetectable concentrations throughout the rest of the month.

Alexandrium was almost completely absent from Southern California phytoplankton samples in January and February, but increased dramatically by the beginning of March. This dinoflagellate was observed at the beginning of the month at sites in San Luis Obispo and Santa Barbara counties. By mid month there were observations of *Alexandrium* near Catalina Island and inside San Diego Bay. By the last week of March *Alexandrium* was detected along all Southern California counties. The highest relative abundance was observed at Pismo Pier. Low levels of PSP toxins were detected in the beginning of March at sites in San Luis Obispo County. By the third week of the month toxin concentrations had exceeded the alert level in San Luis Obispo and Santa Barbara counties. PSP concentrations increased from 80 µg on March 14 to 258 µg on March 28 in sentinel mussels from the Cal Poly Pier. Similarly, mussel samples from Santa Barbara exceeded the alert level by the third week of the month, reaching 354 µg at an offshore aquaculture lease by March 21. Mussels from northern Ventura County contained 632 µg of PSP toxins on March 29. High concentrations of these toxins were also detected in mussels from Redondo Beach on March 23 (306 µg). In a rare occurrence, PSP toxins exceeded the alert level inside San Diego Bay on March 13 (112 µg).

The distribution and relative abundance of *Alexandrium* along the Southern California coast continued in April and increased at a number of offshore and onshore sampling stations. Of particular significance was the occurrence of *Alexandrium* greater than 22 miles offshore near Catalina, Santa Barbara, and San Nicolas islands. The highest relative abundances were observed at sites in northern San Diego County and offshore of Los Angeles. This dinoflagellate decreased in relative abundance through the last three weeks of the month but continued to be observed through the third and fourth weeks at various locations. By the first week of April the elevated PSP toxin

concentrations detected in March had reached the highest levels in Santa Barbara and had declined somewhat in San Luis Obispo and Ventura relative to the last week of March. Toxin concentrations above the alert level were detected in mussels from San Luis Obispo, Santa Barbara, and Ventura counties. Also significant was the rare detection of low levels of these toxins in mussels from Agua Hedionda Lagoon and La Jolla (San Diego County).

Although significant numbers of *Alexandrium* persisted along the entire Southern California coast during May, the relative abundance did decrease at a number of offshore and onshore sampling stations compared to observations in March and April. Low levels of PSP toxins persisted at sites in Santa Barbara through the first half of May. A sample of rock scallop viscera, collected near Anacapa Island on May 26, contained a high concentration of these toxins (456 µg). The scallop adductor was found to contain a low concentration of toxins (46 µg). By June toxin levels had declined below the detection limit at all Southern California sites, although *Alexandrium* continued to be present between San Luis Obispo and Ventura counties.

The relative abundance of *Alexandrium* increased slightly at some Northern California sites in June, particularly at sites between San Mateo and Monterey counties. PSP toxins were detected in shellfish samples from Pescadero Beach (San Mateo County) (June 15) and the Santa Cruz Pier (June 14, 21, and 28). The relative abundance of this dinoflagellate increased at some sites in Monterey Bay during July, followed by an increase in shellfish toxin levels. PSP toxin concentrations increased through the first three weeks of July at the Santa Cruz Pier, reaching 316 µg by July 19. A low level of these toxins was also detected in mussels from Pescadero Beach in San Mateo County (July 26). *Alexandrium* was also observed in samples collected offshore of San Francisco and San Mateo counties by the Gulf of the Farallones National Marine Sanctuary (GFNMS). The relative abundance of this dinoflagellate decreased at several locations through August. The elevated PSP toxin concentrations detected in July at the Santa Cruz Pier peaked by August 2 (324 µg), then declined to low levels throughout the month.

There was a slight increase in numbers of *Alexandrium* along the Northern California coast in September. There was a brief increase in toxicity above the alert level in sentinel mussels from Drakes Estero on September 12 (100 µg). Low concentrations of these toxins were also detected at two sites inside Humboldt Bay. *Alexandrium* continued to be observed in significant numbers between San Luis Obispo and San Diego counties in September and was detected at more sites within this range. These increased observations were most notable at offshore sites along the San Luis Obispo coast. PSP toxins were detected by the second week of September in shellfish samples from San Luis Obispo County. By the third week toxin concentrations reached 164 µg inside Morro Bay. High toxin levels were also detected in mussels from Vandenberg (Santa Barbara County) on September 26 (148 µg).

The relative abundance of *Alexandrium* increased dramatically at a number of sites along the San Luis Obispo coast in October. The highest cell numbers were observed

at Cayucos Pier (October 30) and offshore of Diablo Cove (October 19). The elevated concentrations of PSP toxins detected in the latter half of September inside Morro Bay continued through October. Toxin concentrations reached 490 μg shellfish tissue (October 9) and 461 μg (October 30) at two different locations in Morro Bay. Low toxin levels were also detected in mussels from Avila and Vandenberg, the latter representing a decrease from elevated levels the last week of September. Low levels of PSP toxins continued to be detected at a number of sites along the Northern California coast in October. By the end of the month the PSP toxin levels had increased above the alert level in sentinel mussels from the Monterey commercial pier (165 μg , October 30). Of note is the extremely high toxin concentration in rock scallop viscera from the same site in Monterey: 1289 μg (October 30). These elevated toxin concentrations declined in mussels by November 7 but remained high in scallop viscera. Scallop adductor muscle samples remained low or nondetectable for the PSP toxins during this time.

The distribution of *Alexandrium* increased in November along the Southern California coast, with a southward extension in range through Los Angeles and offshore as well. The elevated concentrations of PSP toxins detected inside Morro Bay in September and October continued through the first two weeks of November. Toxin concentrations reached 556 μg by November 2. Elevated toxin levels were also detected in mussels from San Simeon Pier on November 2 (312 μg) and the Cal Poly Pier in Avila on November 7 (324 μg). *Alexandrium* was present in significant numbers through December, although the relative abundance declined somewhat compared to previous months. The observation of this dinoflagellate offshore near Santa Cruz Island is of note. Low concentrations of PSP toxins continued to be detected in mussels from several sites along the San Luis Obispo coast. Low levels of these toxins persisted throughout most of the month inside Morro Bay and at the Cal Poly pier in Avila (Figure 3). These toxins were also detected in mussels from Cayucos Point and in lobster viscera from samples collected near Anacapa Island. Low levels of these toxins continued to be detected inside Drakes Estero throughout the end of the December.

Domoic Acid Toxicity and *Pseudo-nitzschia* Observations

Measurable concentrations of domoic acid were found in 39 samples during 2006 (Table 8), compared to 40 positive samples in 2005. Domoic acid was detected in samples from the following coastal counties: Del Norte, Humboldt, Santa Cruz, 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 10 of the 39 positive samples from the following three counties: Humboldt, Santa Barbara, Ventura, and Orange. Six of the 10 samples above the alert level were lobster viscera from the Channel Islands, and these samples contained the highest concentration of domoic acid (169 ppm) detected during 2006. The highest level of this toxin found in molluscan shellfish was 79 ppm in razor clams from Humboldt County.

The magnitude of domoic acid toxicity in 2006 was similar compared to 2005, however the temporal and geographic distribution differed, the latter expanding to include

additional Southern California counties. *Pseudo-nitzschia* relative abundance increased in late January through February offshore of Los Angeles. By March there were elevated numbers of this diatom along most of the Southern California coast. Domoic acid levels began increasing in March and continued through April (Figure 5), primarily along the Southern California coast between San Luis Obispo and San Diego counties. The highest percent compositions of this diatom were observed in October in San Diego County.

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

$$\text{RAI} = (a \cdot b) / c$$

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* (Figure 6) have less importance when the RAI is determined (Figure 7). The period of maximum RAI values for *Pseudo-nitzschia* observations during 2006 (Figure 7) is in agreement with the temporal pattern of measurable domoic acid in shellfish samples (Figure 5).

As discussed earlier, detailed accounts of toxigenic phytoplankton distribution and biotoxin concentrations can be found in the monthly reports. The following is a brief account of domoic acid and *Pseudo-nitzschia* activity during 2006.

Pseudo-nitzschia was observed at many sites along the Southern California coast in February. Increased numbers of this diatom were observed at sites offshore near Catalina and San Nicolas islands and offshore of Newport Harbor (Orange County). The relative abundance of *Pseudo-nitzschia* was significantly higher at San Nicolas Island (February 6) and offshore of Newport Beach (February 23) than other Southern California sites. *Pseudo-nitzschia* continued to increase in distribution and relative abundance along the Southern California coast through March. Domoic acid was detected in shellfish samples by the third week of March. Alert levels of this toxin were detected in mussels from Santa Barbara (22 ppm), lobster viscera from the Channel Islands (70 ppm), and sardine viscera from the Los Angeles - Orange County region. The relative abundance of *Pseudo-nitzschia* decreased somewhat in April. Domoic acid concentrations exceeded the alert level in mussels collected from an oil platform offshore of Los Angeles and Orange counties during the second week of April (20 ppm). Lower concentrations of this toxin were detected in shellfish samples from San Diego, Los Angeles, and Santa Barbara counties. A sample of razor clams from Humboldt County also contained a high level of domoic acid in April (79 ppm, March 29). By the beginning of May domoic acid had declined below the detection limit at all sampling sites.

The relative abundance of *Pseudo-nitzschia* increased somewhat at sites in Monterey Bay in June. Low concentrations of domoic acid were detected in sentinel mussels from the Santa Cruz Pier on June 21 and 28 (1.3 ppm and 7.1 ppm, respectively). The relative abundance of this diatom continued to increase slightly in July at some locations, including Monterey Bay. A low level of domoic acid was detected in sentinel mussels from the Santa Cruz Pier on July 12 (6 ppm). Although *Pseudo-nitzschia* continued to be observed along much of the California coast throughout the remainder of 2006, the relative abundances were lower than in previous months. Domoic acid was not detected in shellfish samples collected between August and December. Samples of lobster viscera from the Channel Islands contained very high levels of domoic acid at the end of December.

2006 PSP QUARANTINES AND RELATED HEALTH ADVISORIES

On March 24 the State Public Health Officer issued a health advisory warning the public not to eat sport-harvested bivalve shellfish or the viscera of sardines, anchovies, lobster (also known as lobster “tomale”), and crab (sometimes called crab “butter”) from the Southern California coast (San Luis Obispo through San Diego counties). This advisory was issued after dangerous levels of domoic acid were detected in mussels, sardines, and lobster viscera anchovies from this region, which increased the likelihood of this toxin being present in the other seafood items listed.

The annual quarantine on the sport-harvesting of mussels went into effect on May 1 as scheduled. The annual mussel quarantine applies only to sport-harvested mussels along the entire California coastline, including all bays and estuaries. Routine biotoxin monitoring is maintained throughout this period. The annual quarantine does not affect the certified commercial shellfish growing areas in California. The press release issued for the annual mussel quarantine also reminded the public that the March 24 health advisory was still in effect. The annual quarantine on the sport-harvesting of mussels was rescinded on midnight, October 31, as scheduled, except for San Luis Obispo County. The quarantine remained in effect for this region due to persistent elevated levels of the PSP toxins and was not rescinded until January 4, 2007.

There were no reported human illnesses or deaths due to PSP or domoic acid poisoning in 2006.

REFERENCES

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

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

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

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

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

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

TABLES 1 – 8

Table 1. Total number of shellfish samples collected per coastal county in 2006 for PSP assay.

COUNTY	# SAMPLES
Del Norte	14
Humboldt	100
Mendocino	2
Sonoma	1
Marin	378
Contra Costa	2
San Francisco	2
San Mateo	17
Santa Cruz	60
Monterey	11
San Luis Obispo	237
Santa Barbara	155
Ventura	35
Los Angeles	17
Orange	4
San Diego	94
TOTAL	1129

Table 2. Number of shellfish samples collected by program participants, per coastal County, in 2006 for PSP assay.

COUNTY (North to South)	COMMERCIAL GROWERS	COUNTY AGENCIES	STATE AGENCIES	FEDERAL AGENCIES	OTHER PARTICIPANTS	TOTAL
Del Norte	--	14	--	--	--	14
Humboldt	96	4	--	--	--	100
Mendocino	--	2	--	--	--	2
Sonoma	--	--	1	--	--	1
Marin	346	--	32	--	--	378
Contra Costa	--	--	2	--	--	2
San Francisco	--	2	--	--	--	2
San Mateo	--	17	--	--	--	17
Santa Cruz	--	10	50	--	--	60
Monterey	--	--	1	--	10	11
San Luis Obispo	192	--	40	1	4	237
Santa Barbara	94	--	50	7	4	155
Ventura	--	13	--	7	15	35
Los Angeles	--	17	--	--	--	17
Orange	--	--	--	--	4	4
San Diego	43	--	18	12	21	94
TOTAL =	771	79	194	27	58	1129

Table 3. Program participants by county that submitted shellfish samples in 2006 for PSP assay.

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

	CDPH Volunteer
	Naval Air Station, Pt. Mugu
Los Angeles	Los Angeles County Health Department
Orange	Aquarium of the Pacific Long Beach
San Diego	Carlsbad Aquafarm, Inc.
	CDPH Volunteer
	Scripps Institute of Oceanography
	U.S. Navy

Table 4. Number and species of samples collected in 2006 for PSP assay.

SAMPLE TYPE	# SAMPLES
Bay Mussels ¹ :	
Sentinel	130
Wild	20
Cultured	204
Total Bay Mussels	336
Sea Mussels ² :	
Sentinel	220
Wild	177
Total Sea Mussels	367
Mixed Bay and Sea Mussels	17
Total Mussels	752
Pacific Oysters ³	
Cultured	342
Rock Scallops	7
Other ⁴	28
TOTAL	1129

¹ *Mytilus galloprovincialis* or *M. trussulus*

² *Mytilus californianus*

³ *Crassostrea gigas*

⁴ Razor clam, Gaper clam, Littleneck clam, Pismo clam, Spiny Lobster

Table 5. Total number of shellfish samples analyzed for domoic acid, per coastal county, in 2006.

COUNTY	# SAMPLES
Del Norte	4
Humboldt	7
Mendocino	0
Sonoma	0
Marin	22
San Francisco	0
San Mateo	1
Santa Cruz	35
Monterey	5
San Luis Obispo	52
Santa Barbara	44
Ventura	20
Los Angeles	11
Orange	6
San Diego	43
TOTAL	250

Table 6. Total number of phytoplankton samples collected per coastal county in 2006.

COUNTY	# SAMPLES
Del Norte	17
Humboldt	54
Mendocino	3
Sonoma	13
Marin	252
Contra Costa	8
San Francisco	50
San Mateo	58
Santa Cruz	113
Monterey	110
San Luis Obispo	247
Santa Barbara	216
Ventura	123
Los Angeles	185
Orange	15
San Diego	113
TOTAL	1577

Table 7. Date and location of shellfish samples containing detectable levels of PSP toxins during 2006.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	PSP TOXINS (ug/100 g)
JANUARY				
1/24/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	49
1/31/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	70
1/31/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	42
1/31/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	40
1/31/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	93
FEBRUARY				
2/3/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	137
2/3/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	36
2/3/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	43
2/3/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	71
2/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	62
2/7/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	41
2/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
2/14/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	38
2/14/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
2/15/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	33
2/21/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	44
2/21/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	63
2/23/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	72
2/23/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	35
2/23/2006	Marin	Sea Mussel, Sentinel	Drakes Estero, Bed #12	47
2/23/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #7	34
2/23/2006	Marin	Sea Mussel, Sentinel	Drakes Estero, Channel Buoy	167
2/27/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	34
2/28/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	59
2/28/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	40
2/28/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	41
2/28/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	56

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MARCH				
3/1/2006	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	54
3/3/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	43
3/3/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	53
3/3/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	46
3/3/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	118
3/5/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	36
3/5/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	35
3/5/2006	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	36
3/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	66
3/7/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	38
3/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	282
3/7/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	70
3/8/2006	Santa Cruz	Sea Mussel, wild	Natural Bridges	54
3/8/2006	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	118
3/10/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	42
3/10/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	52
3/10/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #9	38
3/10/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	77
3/10/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	36
3/12/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, WQ Station #12	42
3/13/2006	San Diego	Sea Mussel, wild	San Diego Bay, U.S. Navy Pier	112
3/14/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	42
3/14/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
3/14/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	80
3/15/2006	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	50
3/16/2006	San Diego	Mixed Sea/Bay Mussels	La Jolla, Scripps Pier	38
3/17/2006	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	49
3/17/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	91
3/17/2006	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon	41
3/19/2006	Los Angeles	Sea Mussel, wild	Portuguese Bend	44
3/20/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	34

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3/20/2006	Ventura	Sea Mussel, wild	Pt. Mugu	44
3/21/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
3/21/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	36
3/21/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	226
3/21/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	354
3/21/2006	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	66
3/22/2006	Santa Cruz	Sea Mussel, wild	Santa Cruz Pier	43
3/22/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	135
3/22/2006	Los Angeles	Sea Mussel, wild	Portuguese Bend	51
3/23/2006	Los Angeles	Bay Mussel, wild	Redondo Beach Pier	306
3/23/2006	Orange	Sea Mussel, wild	Santa Catalina Ch., Plt Eureka	49
3/23/2006	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon	45
3/23/2006	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	43
3/24/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
3/24/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	59
3/24/2006	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	72
3/27/2006	Los Angeles	Sea Mussel, wild	Malibu Beach	66
3/28/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	48
3/28/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	258
3/29/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	158
3/29/2006	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	632
3/30/2006	San Diego	Sea Mussel, wild	La Jolla, Scripps Pier	42
APRIL				
4/1/2006	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon	39
4/4/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	38
4/4/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
4/4/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	41
4/4/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	118
4/5/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
4/5/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	744
4/6/2006	San Diego	Mixed Sea/Bay Mussels	La Jolla, Scripps Pier	36
4/7/2006	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	348

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4/8/2006	San Diego	Bay Mussel, cultured	Agua Hedionda Lagoon	34
4/10/2006	Ventura	Sea Mussel, wild	Santa Cruz Is., Prisoners Hrbr	114
4/11/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	46
4/11/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	49
4/12/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	149
4/13/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	445
4/18/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	38
4/19/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	126
4/20/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	169
4/20/2006	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	42
4/24/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	68
4/24/2006	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	37
4/24/2006	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	60
4/26/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
4/26/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	65
4/27/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	55
MAY				
5/2/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	40
5/2/2006	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	34
5/2/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	38
5/4/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	47
5/9/2006	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	35
5/10/2006	Santa Barbara	Sea Mussel, wild	Goleta Pier	34
5/13/2006	Santa Barbara	Rock Scallop viscera	Santa Barbara Harbor	264
5/13/2006	Santa Barbara	Rock Scallop adductor	Santa Barbara Harbor	46
5/17/2006	Ventura	Sea Mussel, wild	Mussel Shoals, Oil Piers	37
5/26/2006	Ventura	Rock Scallop viscera	Ventura, Anacapa Is., Mid	456
5/26/2006	Ventura	Rock Scallop adductor	Ventura, Anacapa Is., Mid	46
JUNE				
6/14/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	53
6/15/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	49
6/15/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	52

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6/21/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	44
6/28/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	68
JULY				
7/5/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	97
7/12/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	112
7/19/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	316
7/26/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	57
7/26/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	290
AUGUST				
8/1/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	44
8/1/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #20	34
8/1/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	44
8/2/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	324
8/8/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	56
8/8/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	39
8/8/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	35
8/9/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	56
8/10/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	44
8/12/2006	Ventura	Rock Scallop, wild	Santa Cruz Is., Pelican Bay	62
8/15/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	41
8/15/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	49
8/16/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	64
8/22/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
8/22/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	42
8/22/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	48
8/22/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	42
8/22/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	40
8/23/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40
8/24/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	42
8/24/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	39
8/28/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	36
8/29/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	43

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8/29/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	41
8/29/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
8/29/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	36
SEPTEMBER				
9/4/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	44
9/5/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	40
9/5/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	42
9/5/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	58
9/5/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	36
9/9/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11	37
9/10/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	43
9/12/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
9/12/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	49
9/12/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	39
9/12/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	52
9/12/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #8	37
9/12/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	100
9/12/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P1	44
9/12/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	63
9/14/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	49
9/14/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11	42
9/15/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	36
9/15/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #38	40
9/15/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	72
9/16/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-11	40
9/17/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	59
9/17/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	88
9/17/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	38
9/19/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	39
9/19/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	50
9/19/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	48
9/19/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	39

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9/19/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, Lease M-614-01 P2	77
9/19/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	164
9/19/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	51
9/19/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	39
9/19/2006	Santa Barbara	Sea Mussel, wild	Vandenberg AFB, Boathouse Dock	66
9/20/2006	Marin	Bay Mussel, Sentinel	Tomales Bay, Lease #M430-11	65
9/20/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	59
9/20/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	40
9/21/2006	Marin	Pacific Oyster, cultured	Tomales Bay, Lease #M430-02	37
9/21/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	47
9/21/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, Lease M-614-01 P2	42
9/24/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	43
9/24/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	76
9/25/2006	Marin	Sea Mussel, Sentinel	Kehoe Beach	62
9/26/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	40
9/26/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	62
9/26/2006	Santa Barbara	Sea Mussel, wild	Vandenberg AFB, Boathouse Dock	148
9/27/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	44
9/27/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	45
9/27/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	141
9/27/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	50
OCTOBER				
10/1/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	107
10/1/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	44
10/3/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	40
10/3/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	49
10/3/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	70
10/4/2006	Monterey	Sea Mussel, wild	Monterey Bay, Fishermans Wharf	54
10/4/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	52
10/4/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	47
10/4/2006	Santa Barbara	Sea Mussel, wild	Vandenberg AFB, Boathouse Dock	43
10/5/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	38

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10/9/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	58
10/9/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	490
10/10/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	40
10/10/2006	Marin	Sea Mussel, Sentinel	Drakes Bay, Fish Dock	43
10/10/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
10/10/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	212
10/10/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	46
10/10/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	79
10/11/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P1	52
10/11/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	183
10/16/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	198
10/16/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	36
10/17/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, Indian Is. Ch.	38
10/17/2006	Humboldt	Sea Mussel, Sentinel	Humboldt Bay, USCG Station	39
10/17/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	37
10/17/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	142
10/18/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	125
10/18/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	39
10/18/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	74
10/22/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	36
10/22/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	242
10/23/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	42
10/23/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	70
10/24/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	124
10/24/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	42
10/29/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #12	57
10/29/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #12	177
10/30/2006	Monterey	Bay Mussel, wild	Monterey Bay, Fishermans Wharf	165
10/30/2006	Monterey	Rock Scallop viscera	Monterey Bay, Fishermans Wharf	1289
10/30/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	87
10/30/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, Lease M-614-01 P2	461
10/30/2006	Santa Barbara	Sea Mussel, wild	Vandenberg AFB, Boathouse Dock	66

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10/31/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	36
NOVEMBER				
11/1/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #11A	55
11/1/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	528
11/2/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, Lease M-614-01 P2	69
11/2/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	556
11/2/2006	San Luis Obispo	Sea Mussel, wild	San Simeon	312
11/3/2006	San Luis Obispo	Sea Mussel, wild	Cayucos Point	57
11/5/2006	San Luis Obispo	Pacific Oyster, cultured	Morro Bay, WQ Station #11A	66
11/5/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	69
11/6/2006	San Luis Obispo	Gaper Clam	Morro Bay, outer breakwater	56
11/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	38
11/7/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	37
11/7/2006	Monterey	Bay Mussel, wild	Monterey Bay, Fishermans Wharf	77
11/7/2006	Monterey	Rock Scallop viscera	Monterey Bay, Fishermans Wharf	1312
11/7/2006	Monterey	Rock Scallop adductor	Monterey Bay, Fishermans Wharf	40
11/7/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	324
11/12/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	64
11/14/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	38
11/14/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	91
11/14/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	81
11/15/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	49
11/15/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	63
11/15/2006	Santa Barbara	Sea Mussel, wild	Vandenberg AFB, Boathouse Dock	38
11/16/2006	San Luis Obispo	Bay Mussel, Sentinel	Morro Bay, Lease M-614-01 P2	56
11/17/2006	Monterey	Sea Mussel, wild	Monterey Bay, Fishermans Wharf	53
11/17/2006	Monterey	Rock Scallop viscera	Monterey Bay, Fishermans Wharf	980
11/19/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	66
11/20/2006	San Luis Obispo	Sea Mussel, wild	Cayucos Point	38
11/21/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	54
11/22/2006	San Mateo	Sea Mussel, wild	Pescadero State Beach	36
11/22/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	40

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11/27/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	39
11/28/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	48
11/29/2006	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	39
11/29/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	46
11/29/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	41
DECEMBER				
12/2/2006	San Luis Obispo	Bay Mussel, wild	Cayucos Pier	40
12/5/2006	Marin	Bay Mussel, cultured	Drakes Estero, Channel Buoy	36
12/5/2006	San Luis Obispo	Sea Mussel, Sentinel	Morro Bay, Lease M-614-01 P2	37
12/5/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	37
12/5/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	47
12/12/2006	Marin	Pacific Oyster, cultured	Drakes Estero, Bed #12	35
12/12/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	38
12/12/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	36
12/12/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	41
12/13/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, Lease M-614-01 P2	38
12/19/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Bed #12	35
12/19/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	40
12/19/2006	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	36
12/21/2006	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	36
12/26/2006	Marin	Bay Mussel, Sentinel	Drakes Estero, Channel Buoy	36
12/26/2006	San Luis Obispo	Bay Mussel, cultured	Morro Bay, WQ Station #11A	44
12/29/2006	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	35

Table 8. Date and location of shellfish samples containing detectable levels of domoic acid during 2006.

DATE	COUNTY	SAMPLE TYPE	SAMPLE SITE	DA (ppm)
JANUARY				
FEBRUARY				
MARCH				
03/15/06	Santa Barbara	Sea Mussel, wild	Goleta Pier	2
03/17/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	22
03/19/06	Los Angeles	Sea Mussel, wild	Portuguese Bend	11
03/21/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	17
03/22/06	Santa Barbara	Sea Mussel, wild	Goleta Pier	7.1
03/05/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	70
03/05/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	35
03/05/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	31
03/23/06	Orange	Sea Mussel, wild	Santa Catalina Ch., Plt Eureka	1.5
03/28/06	San Luis Obispo	Sea Mussel, Sentinel	San Luis Obispo, Cal Poly Pier	1
03/27/06	Los Angeles	Sea Mussel, wild	Malibu Beach	9.3
APRIL				
04/04/06	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	5
04/04/06	San Diego	Bay Mussel, wild	San Diego Bay, U.S. Navy Pier	3.9
04/12/06	Orange	Sea Mussel, wild	Santa Catalina Ch., Plt Eureka	23
04/12/06	Orange	Sea Mussel, wild	Santa Catalina Ch., Plt Eureka	20
04/13/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	7.4
04/12/06	Santa Barbara	Sea Mussel, wild	Goleta Pier	11
04/10/06	Santa Cruz	Sea Mussel, wild	Santa Cruz Is., Prisoners Hrbr	8.9
04/20/06	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	3.5
04/24/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	6.7
04/24/06	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	16
04/21/06	San Diego	Sea Mussel, wild	San Onofre	5.8

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04/21/06	San Diego	Littleneck Clam	San Onofre	15
04/19/06	Los Angeles	Mixed Sea/Bay Mussels	Portuguese Bend	15
04/19/06	Los Angeles	Mixed Sea/Bay Mussels	Portuguese Bend	12
04/27/06	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	8.1
04/27/06	Santa Barbara	Pacific Oyster, cultured	Santa Barbara Ch., M-653-02	8.9
04/27/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	6.5
04/27/06	Santa Barbara	Bay Mussel, cultured	Santa Barbara Ch., M-653-02	6.9
04/26/06	Santa Barbara	Sea Mussel, wild	Goleta Pier	5.3
04/29/06	Humboldt	Clam, razor	Clam Beach, McKinleyville	79
MAY				
05/29/06	Del Norte	Clam, razor	Crescent City, Ender's Beach	4
JUNE				
06/21/06	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	1.3
06/28/06	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	7.1
JULY				
07/12/06	Santa Cruz	Sea Mussel, Sentinel	Santa Cruz Pier	6.5
07/14/06	Santa Cruz	Sea Mussel, wild	Natural Bridges	2.3
AUGUST				
SEPTEMBER				
OCTOBER				
NOVEMBER				
DECEMBER				
12/21/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	156
12/29/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	169
12/29/06	Ventura	Lobster, Spiny, viscera	Ventura, Anacapa Is., Mid	120

FIGURES 1 – 13.

Figure 1a. Locations of shellfish sampling stations during 2006 (Del Norte to Monterey counties).

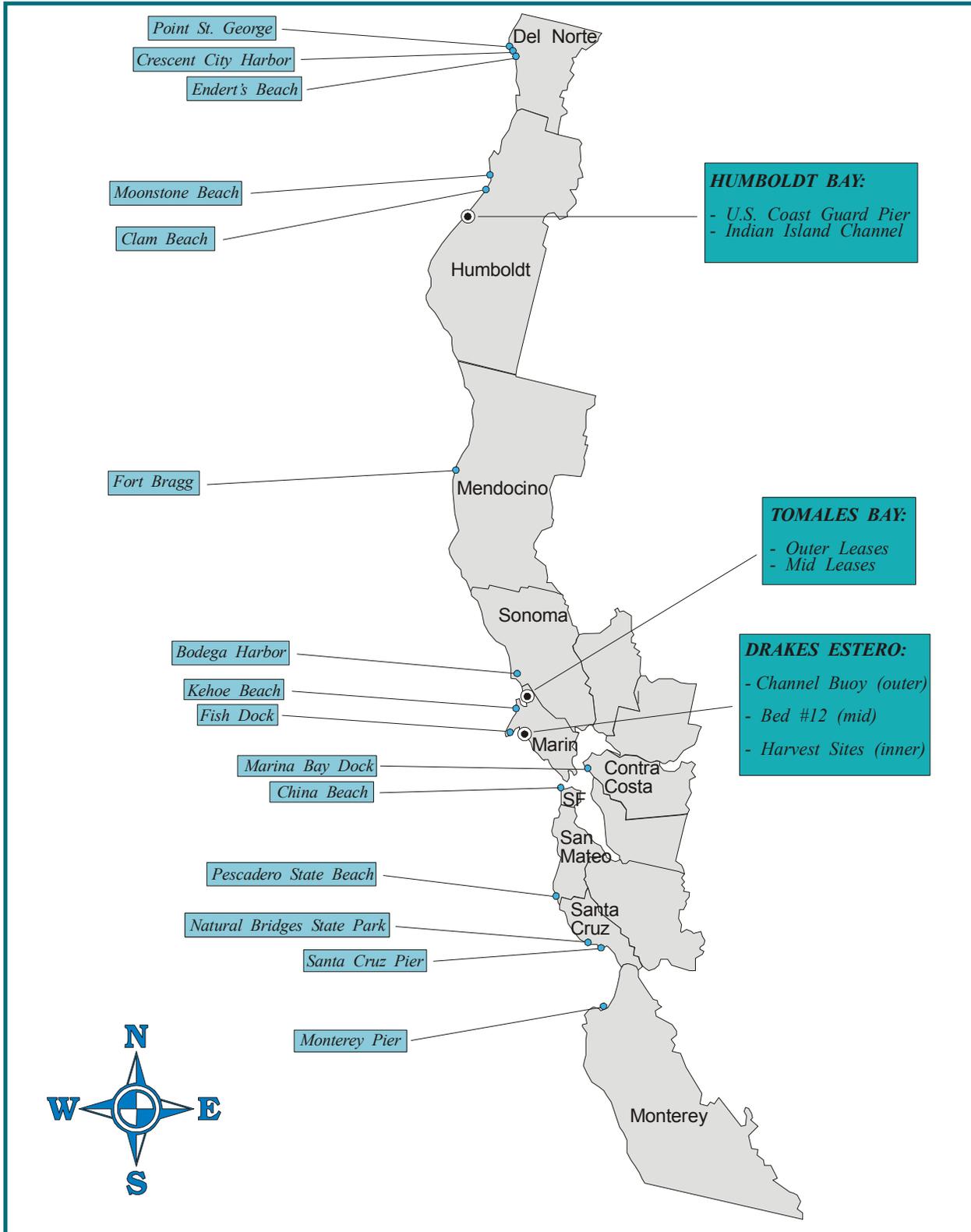


Figure 1b. Locations of shellfish sampling stations during 2006 (San Luis Obispo to San Diego counties).

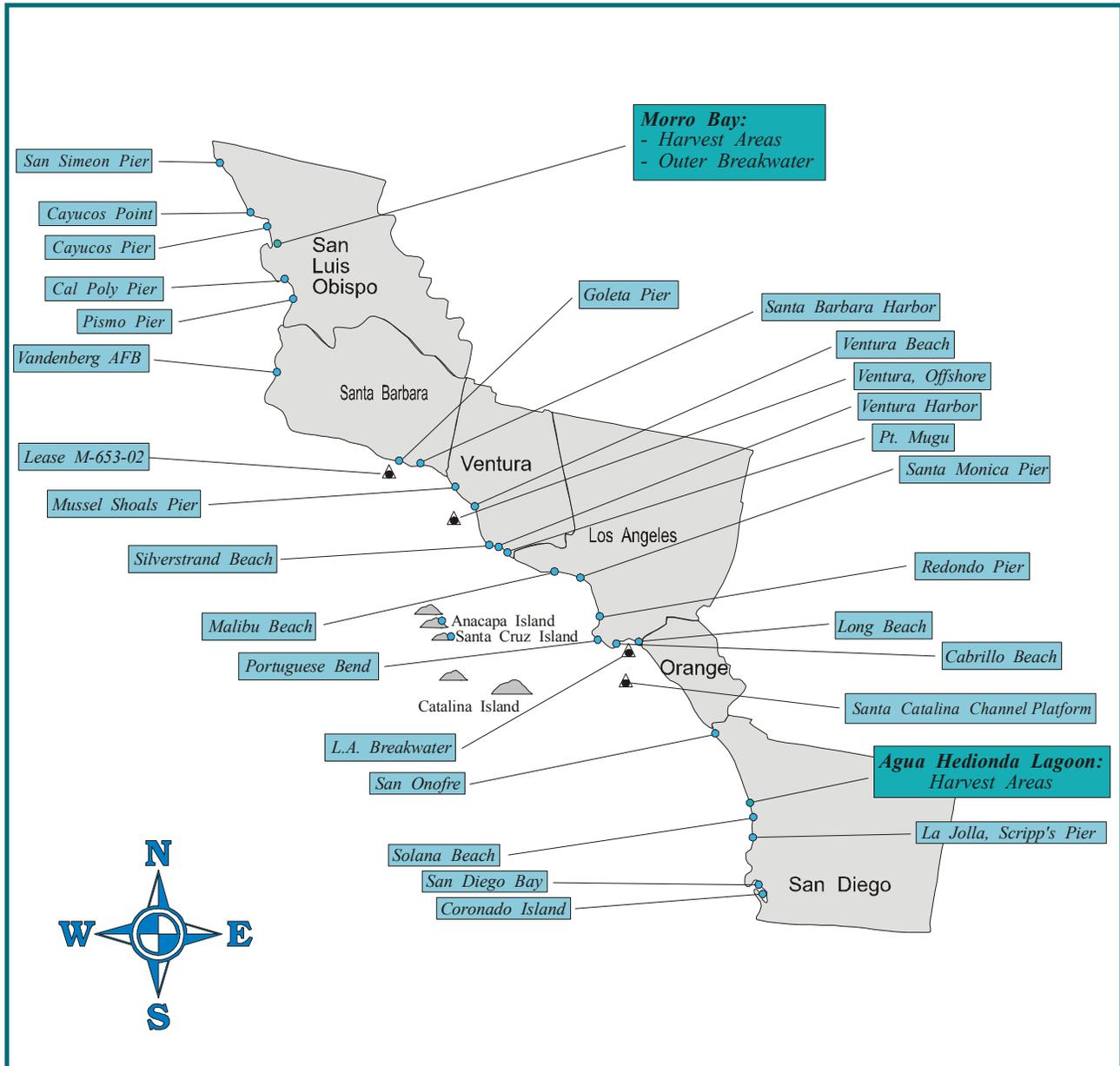


Figure 1c. Locations of phytoplankton sampling stations during 2006 (Del Norte to Monterey counties).

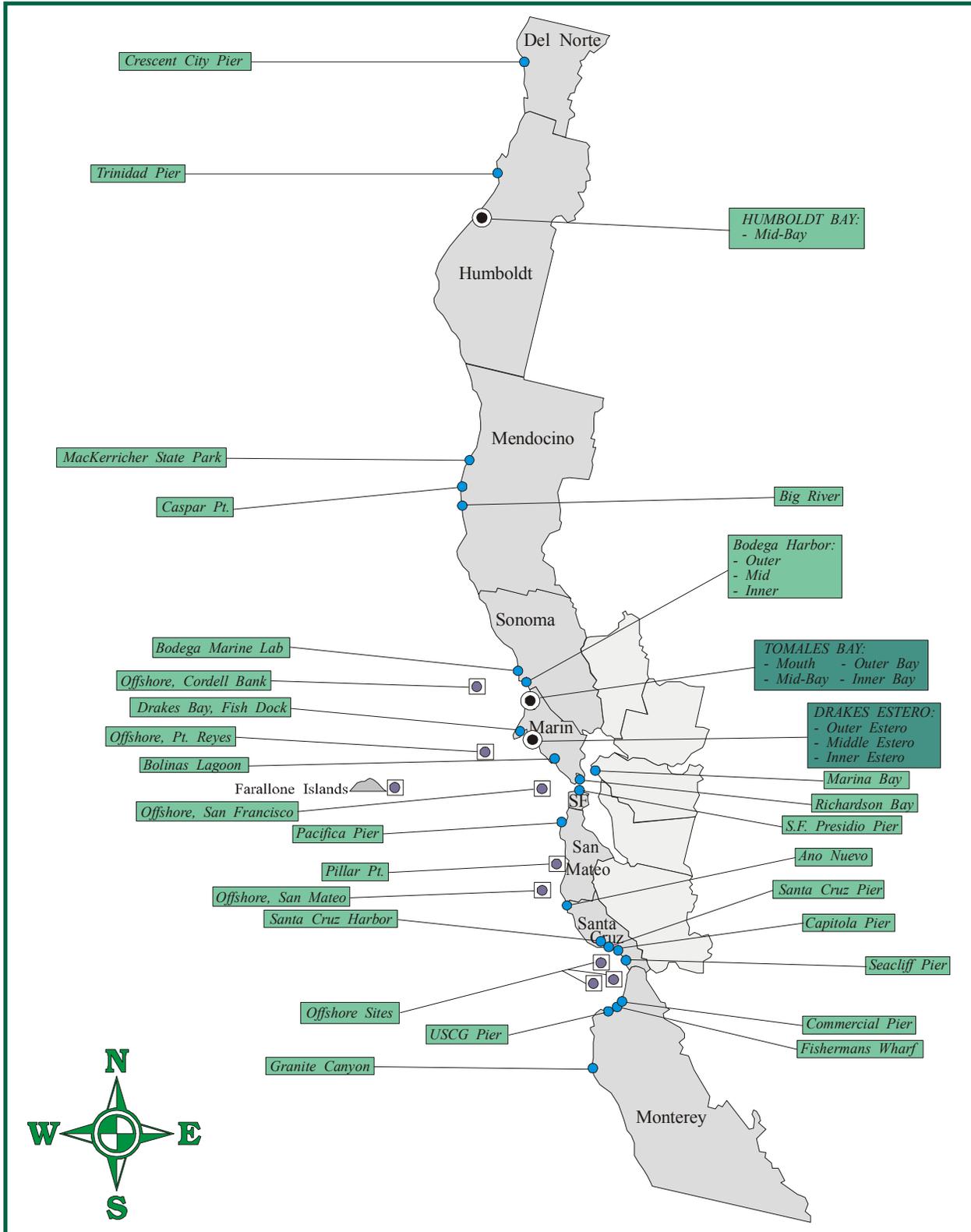


Figure 1d. Locations of phytoplankton sampling stations during 2006 (San Luis Obispo to San Diego counties).

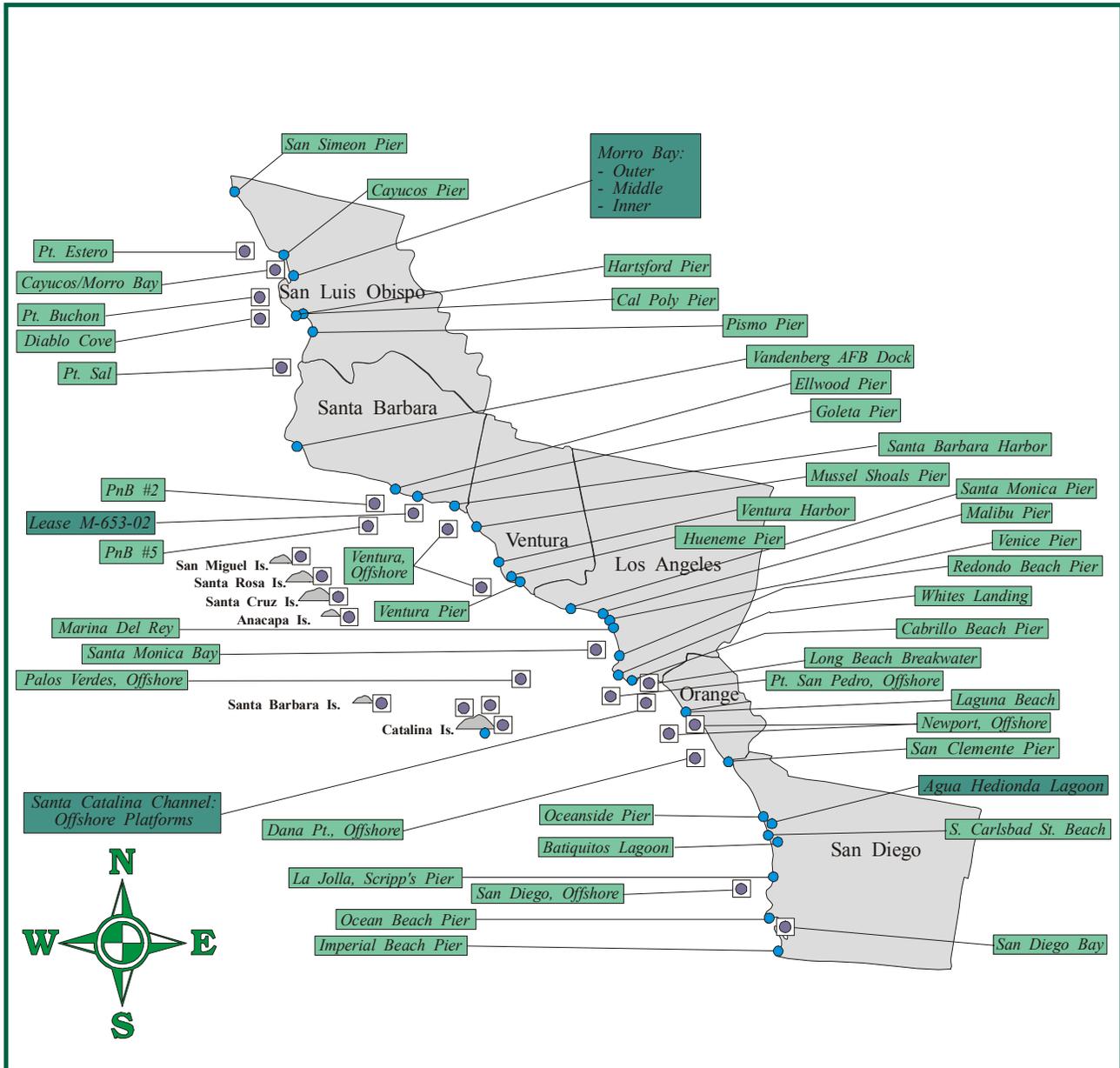


Figure 2. Annual PSP toxin levels in California shellfish from 1991 through 2006.

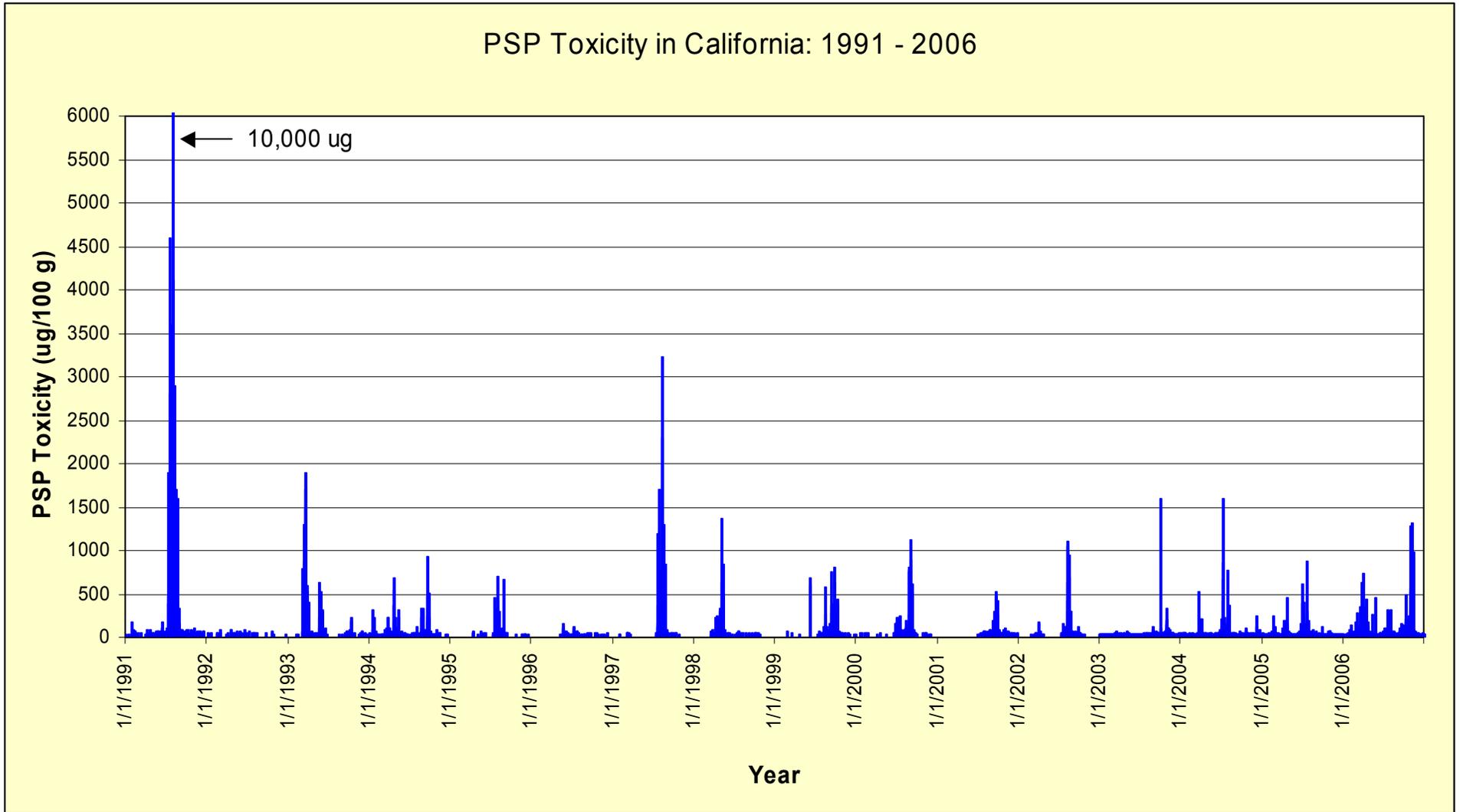


Figure 3. PSP toxin concentration and temporal distribution in California shellfish during 2006.

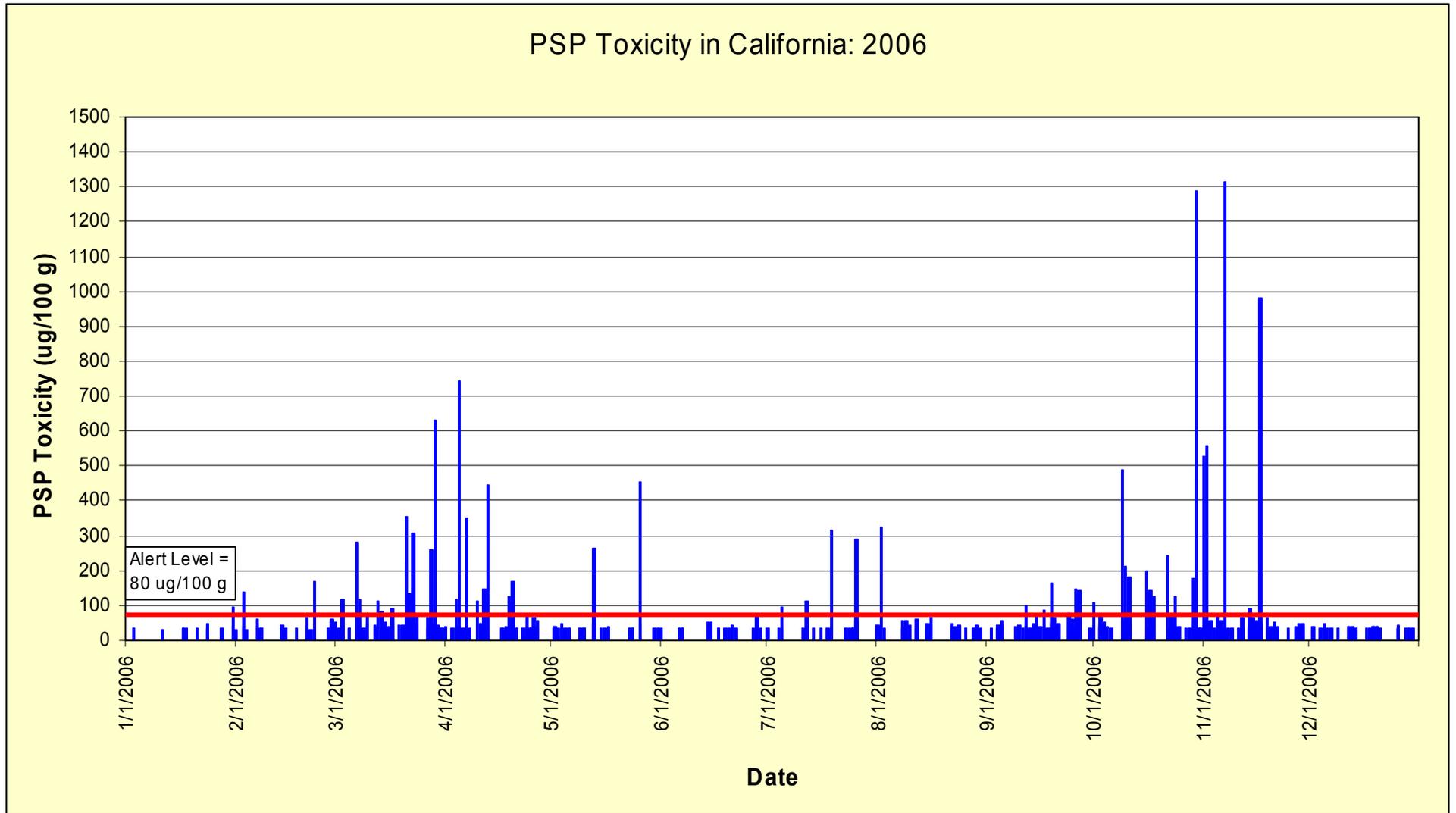


Figure 4. Temporal distribution and percent composition of *Alexandrium* spp. during 2006.

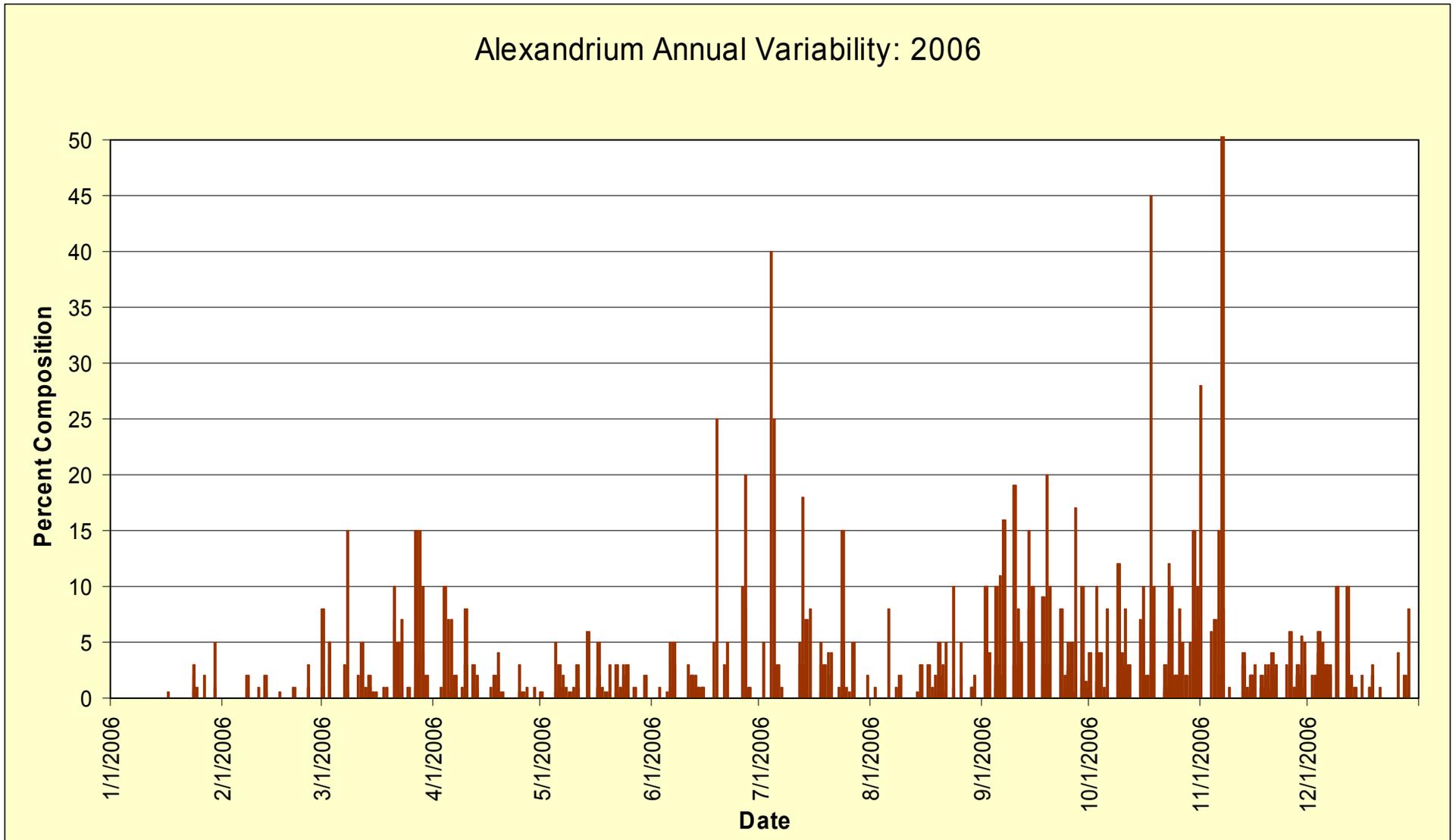


Figure 5. Domoic acid concentration and temporal distribution in California shellfish during 2006.

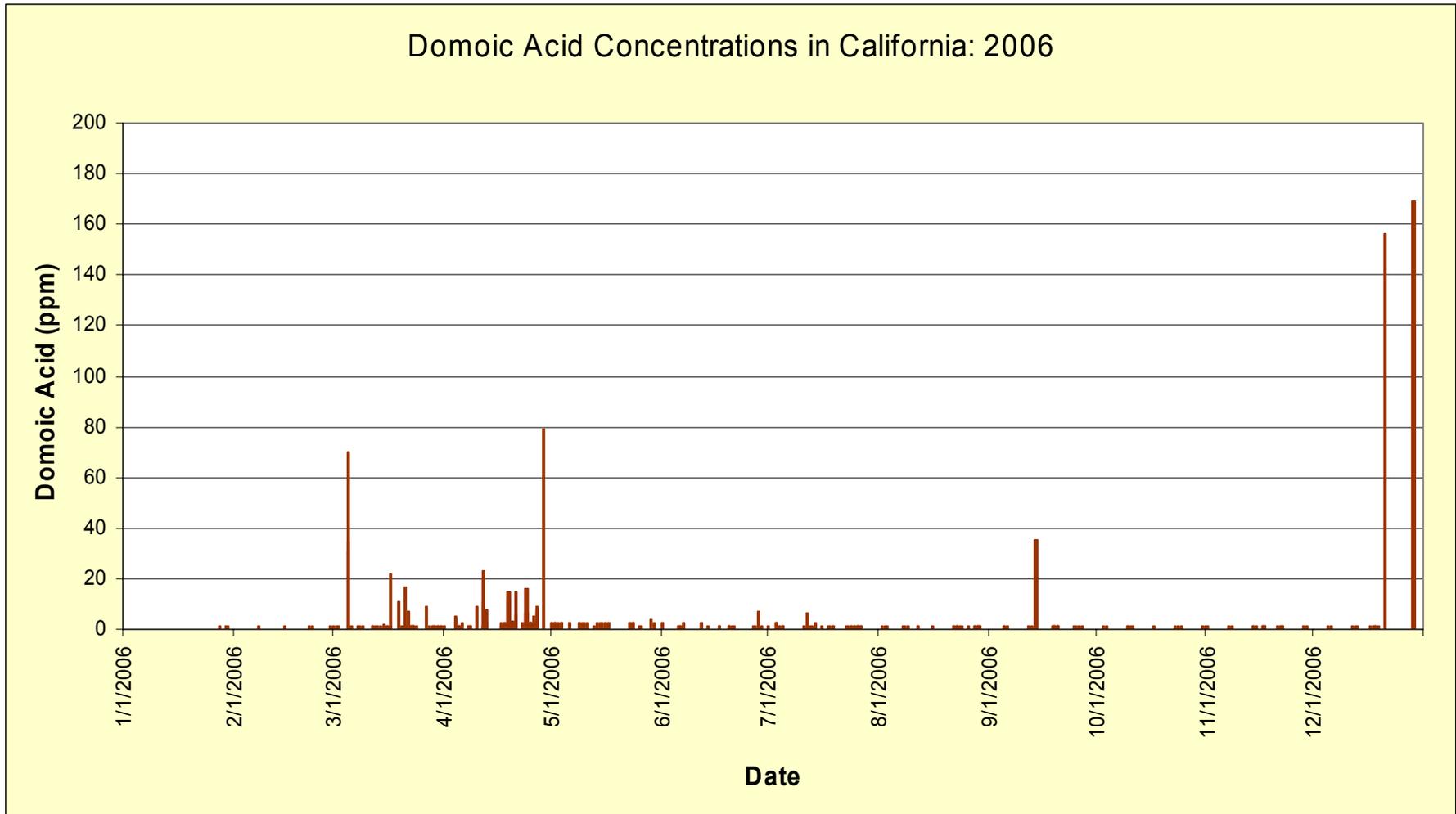


Figure 6. Temporal distribution and percent composition of *Pseudo-nitzschia* spp. during 2006.

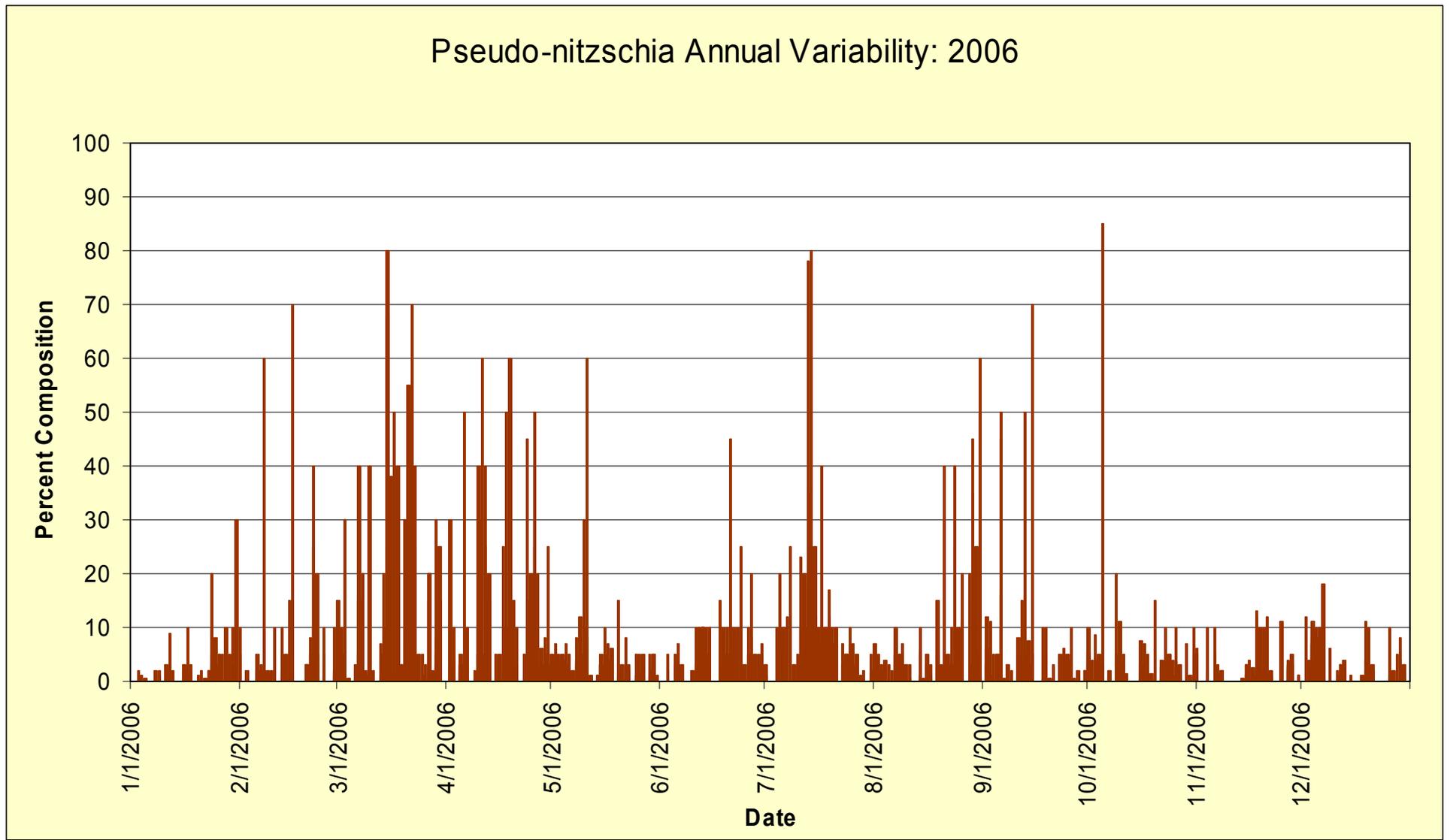


Figure 7. Temporal distribution and relative abundance index (RAI) of *Pseudo-nitzschia* spp. during 2006.

