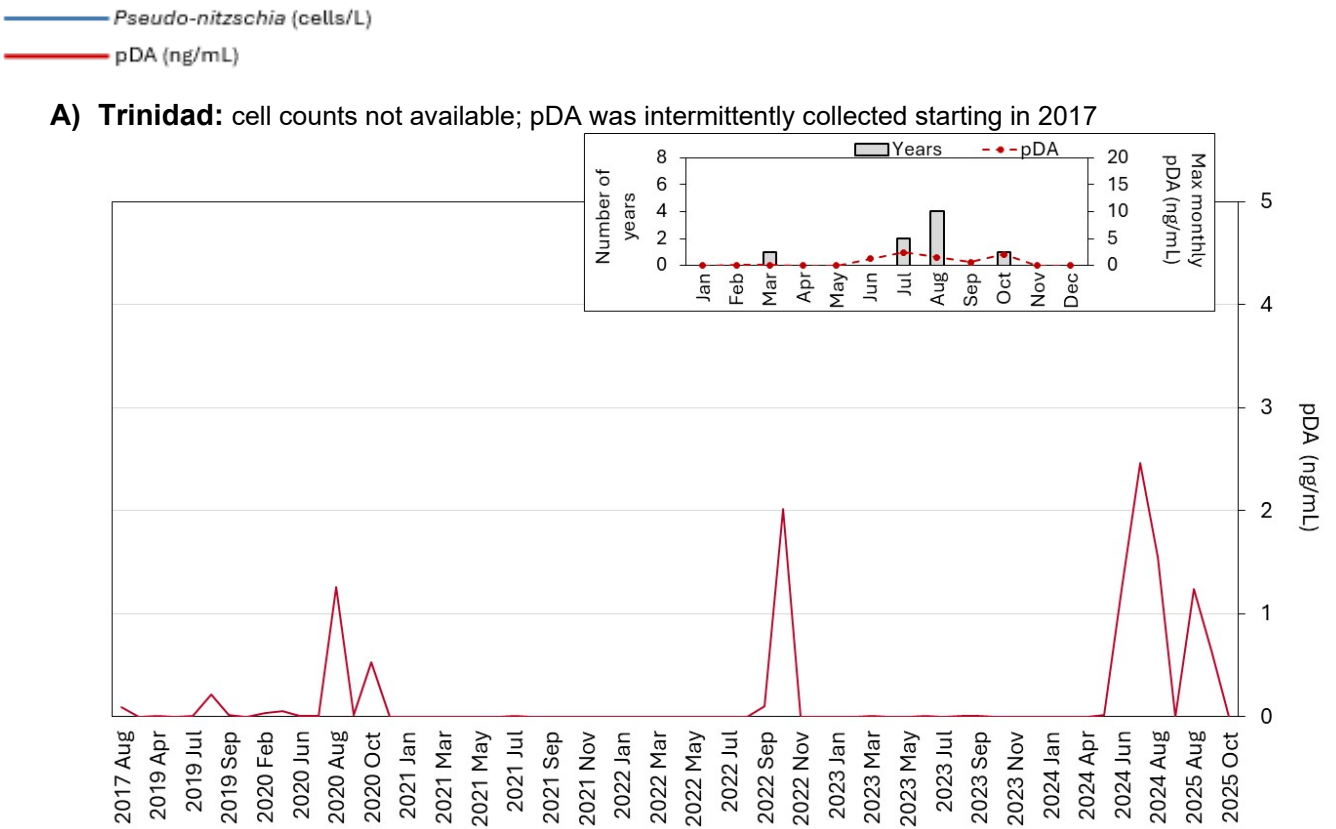


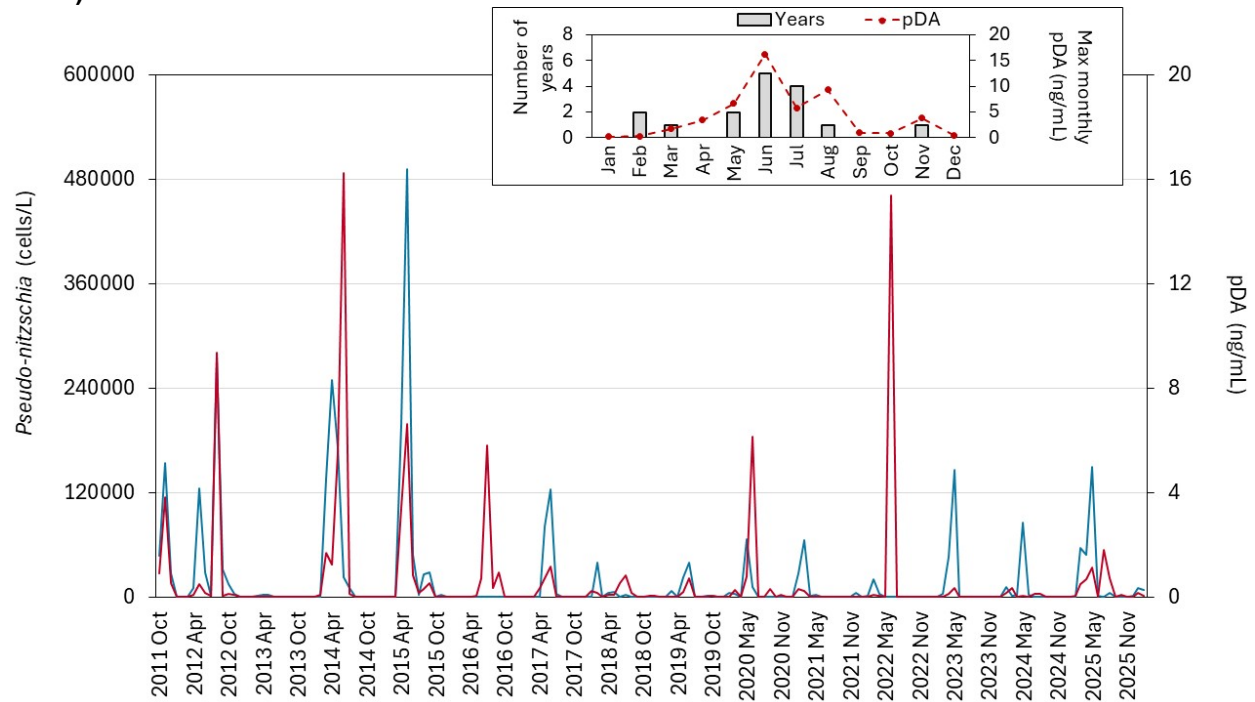
3.6 Marine Harmful Algal Blooms

Marine harmful algal blooms (HABs) are influenced by warming ocean temperatures. They can produce marine biotoxins, such as domoic acid (DA) and paralytic shellfish toxins (PSTs), or otherwise disrupt marine ecosystems. *Pseudo-nitzschia* spp., a diatom which can produce DA, has been of particular concern due to its impacts on marine wildlife, public health, and fisheries (recreational and commercial) in California. Tracking marine HABs along the California coast has become increasingly important as climate change continues to alter the conditions that affect HAB growth and toxicity, and as marine HAB-associated illnesses among marine mammals and birds in southern California have become more prevalent in recent years.

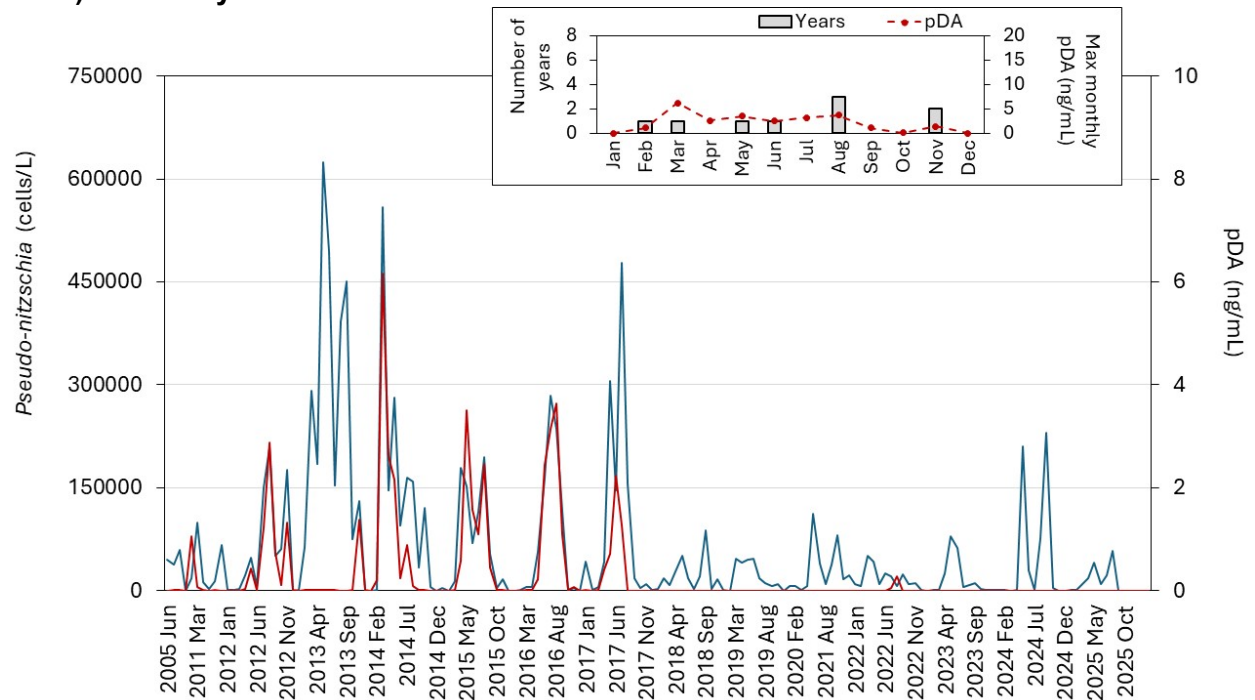
Figure 3.6.1. *Pseudo-nitzschia seriata* Size Class and Particulate Domoic Acid (pDA) Levels at Selected Stations.



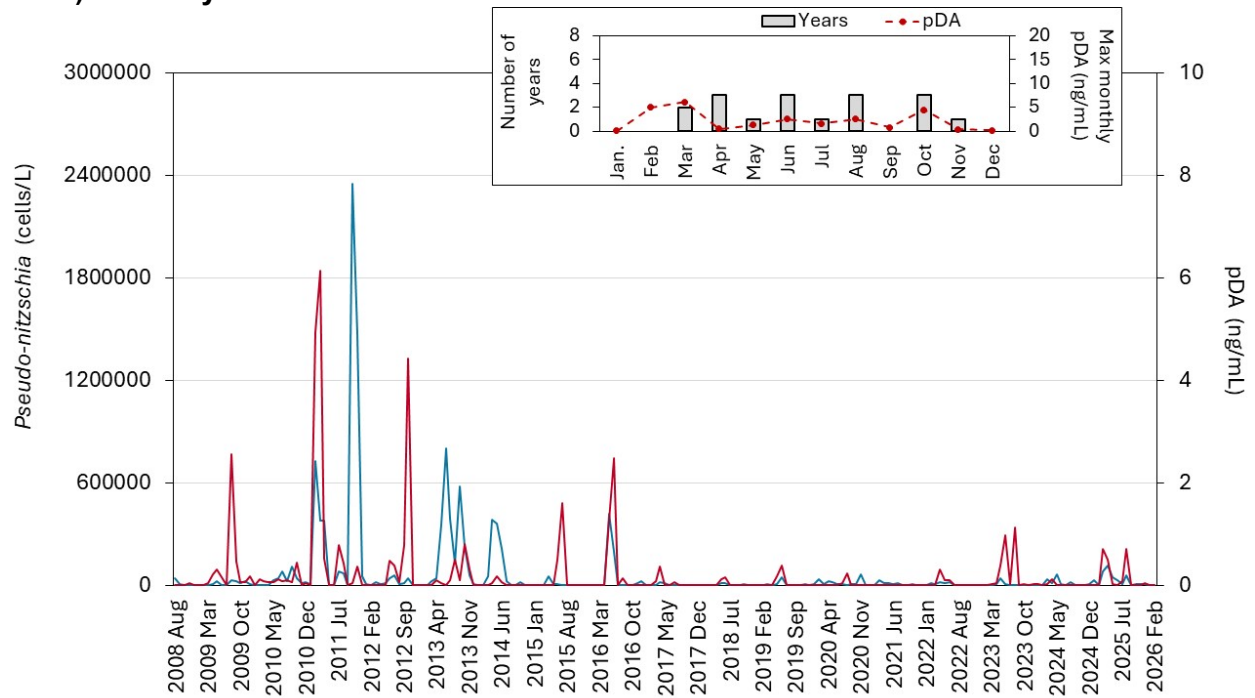
B) Santa Cruz



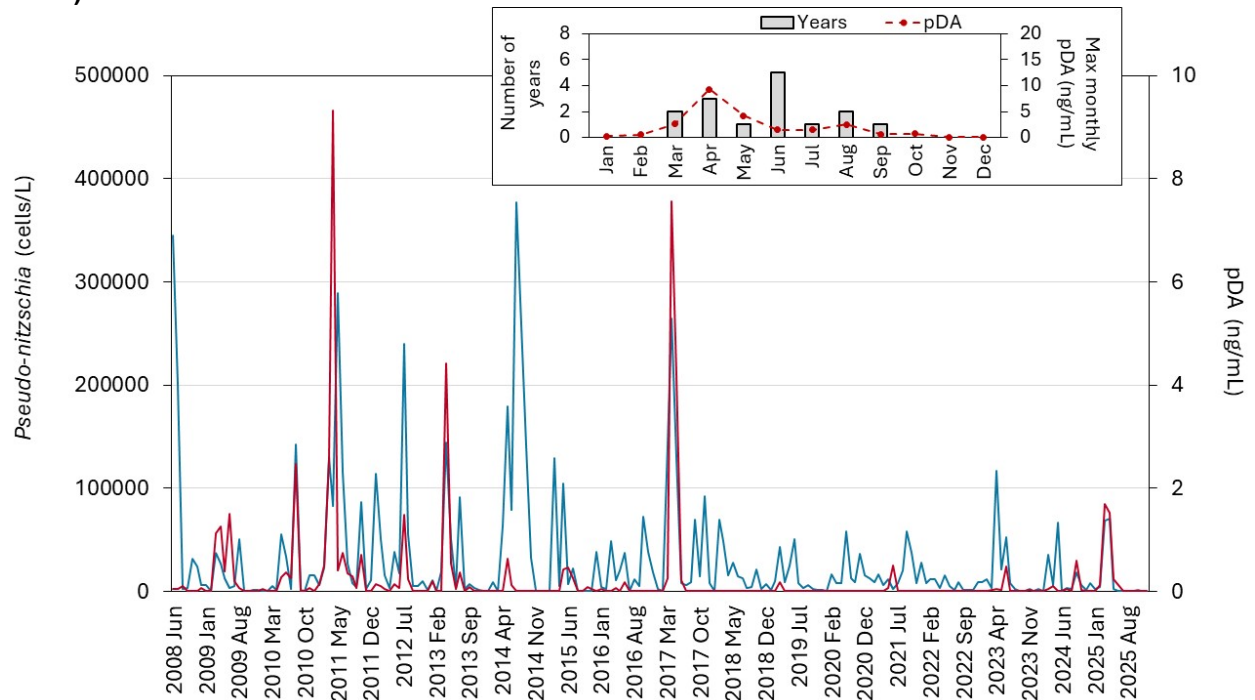
C) Monterey



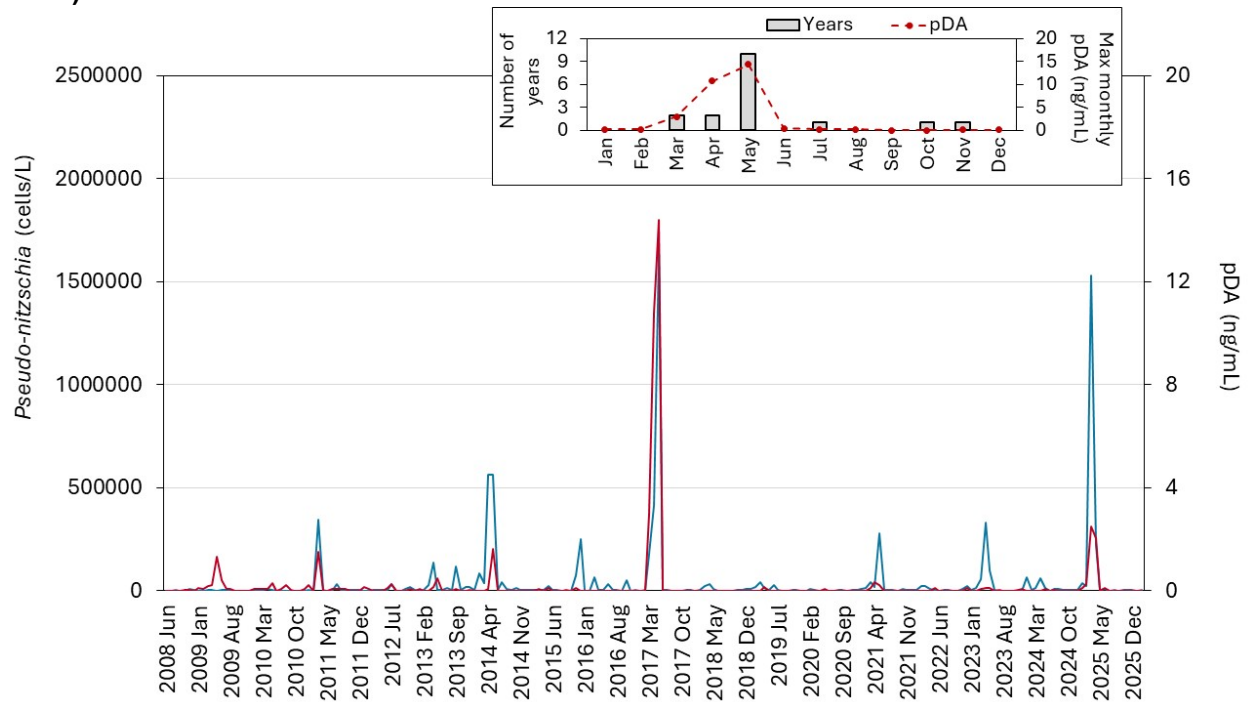
D) Cal Poly



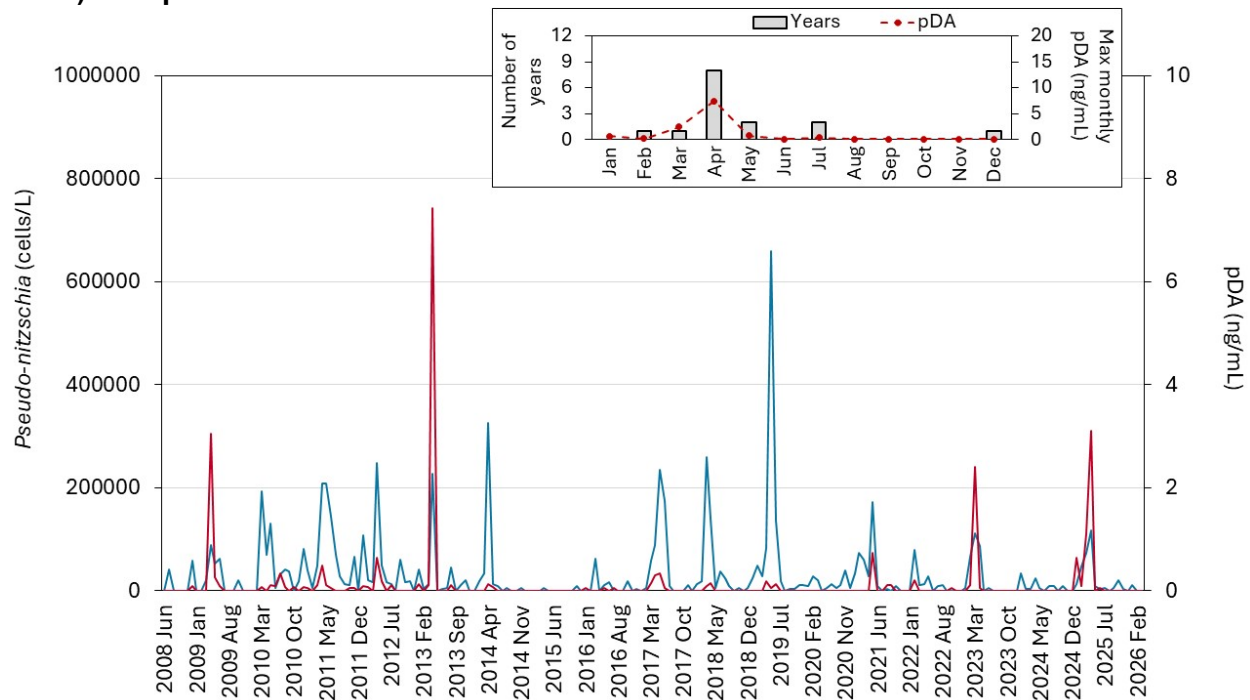
E) Stearns

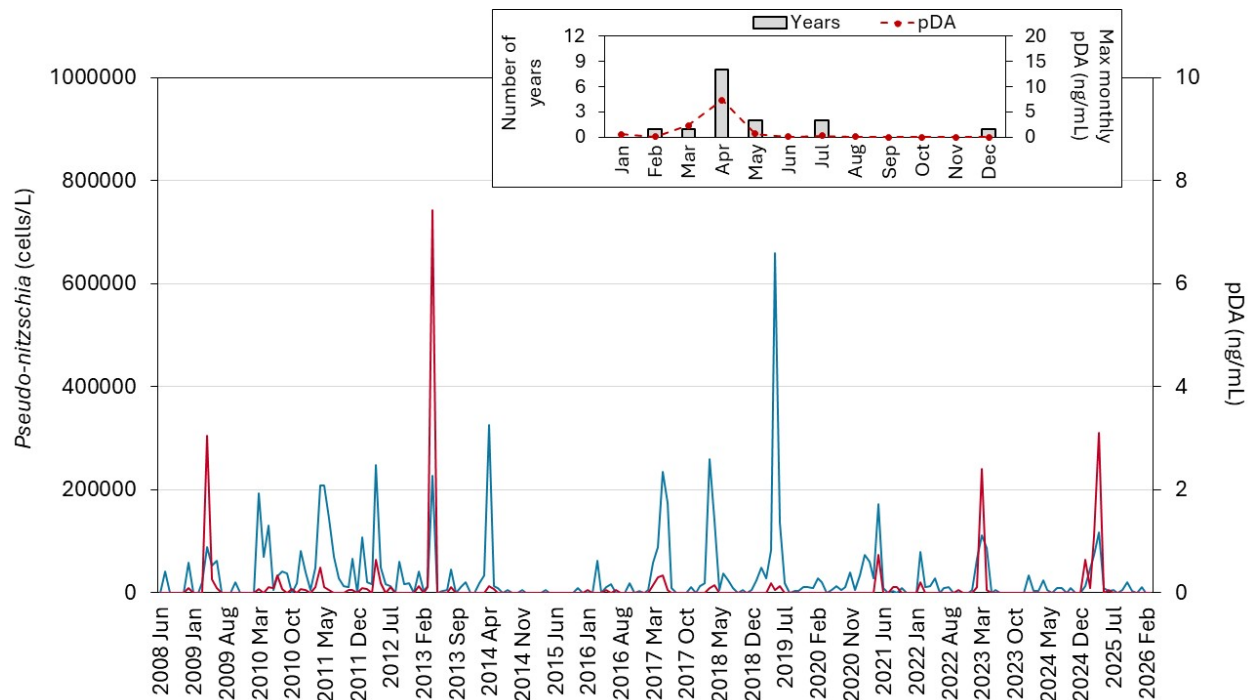


F) Santa Monica



G) Newport



H) Scripps**I) Map of stations**

The graphs show time series of monthly maximum abundance of *Pseudo-nitzschia seriata* size class (cells/L, blue line) and particulate domoic acid (pDA, nanogram per milliliter (ng/mL), red line) concentrations at selected Harmful Algal Bloom Monitoring and Alert Program (HABMAP) stations in California, north to south. Grab water samples were filtered and the domoic acid concentration (in ng/mL) of all material collected on the filter was analyzed for pDA. The eight graphs on the right display the overall maximum pDA by month (across all years, line) and the number of years in which the annual maximum pDA occurred that month (count, column). Source: Analysis by Stanton (2026) using data from the HABMAP obtained from NOAA's Environmental Research Division's Data Access Program (ERDDAP). Map from [SCCOOS](#) (2026)



What does the indicator show?

Marine HABs have increased in frequency and geographic range worldwide since the 1980s due to ocean warming, marine heatwaves, and oxygen loss in coastal waters—factors that climate change is already influencing along the coast of California (IPCC, 2019; see the *Coastal Ocean Temperature* and *Dissolved Oxygen in Coastal Waters* chapters). Marine HABs commonly consist of an overgrowth of algae (diatoms or dinoflagellates) that may produce biotoxins and can result in adverse wildlife and human health effects, ecological disasters, and significant economic losses (Anderson et al., 2021; Sakamoto et al., 2021; Yu et al., 2023). Monitoring marine HABs along the California coast is increasingly important as climate change continues to alter the ocean conditions that promote marine HABs and may influence *Pseudo-nitzschia* cell growth and/or production of DA (Anderson et al., 2026; Sandoval-Belmar et al., 2023). These data document the repeated occurrence of DA-producing *Pseudo-nitzschia* HAB events at multiple sites along the California coastline in recent years, an overall pattern that is expected to continue, although the geographic distribution and seasonality are expected to shift (Saha et al., 2026).

Marine HAB dynamics along the California coastline have regional and site-specific variability, as exemplified by the time-series of monthly maximum cell counts for the *Pseudo-nitzschia* *seriata* size class cells and pDA concentrations from HABMAP sampling sites (**Figure 3.6.1**). **Figure 3.6.1** (inset) also shows overall maximum pDA by month and the number of years in which the annual maximum pDA occurred in each month. The seasonality of monthly maximum pDA across all years and the frequency of maximum pDA in a given month generally coincided. However, there were examples where the maximum pDA occurred in an atypical month, particularly earlier in the year, and was the highest overall concentration across all years. For example, at Cal Poly Pier, the monthly maximum pDA most frequently occurred (three years each) in April, June, August, and October; however, the monthly maximum pDA concentrations across all years was in March, primarily because of the high pDA in March 2011 (6.14 ng/mL). Both *Pseudo-nitzschia* *seriata* size class cell counts and pDA concentrations were typically lowest in winter (December-February) and higher in spring (March to May) with some HAB events occurring during summer and fall. Overall maximum pDA

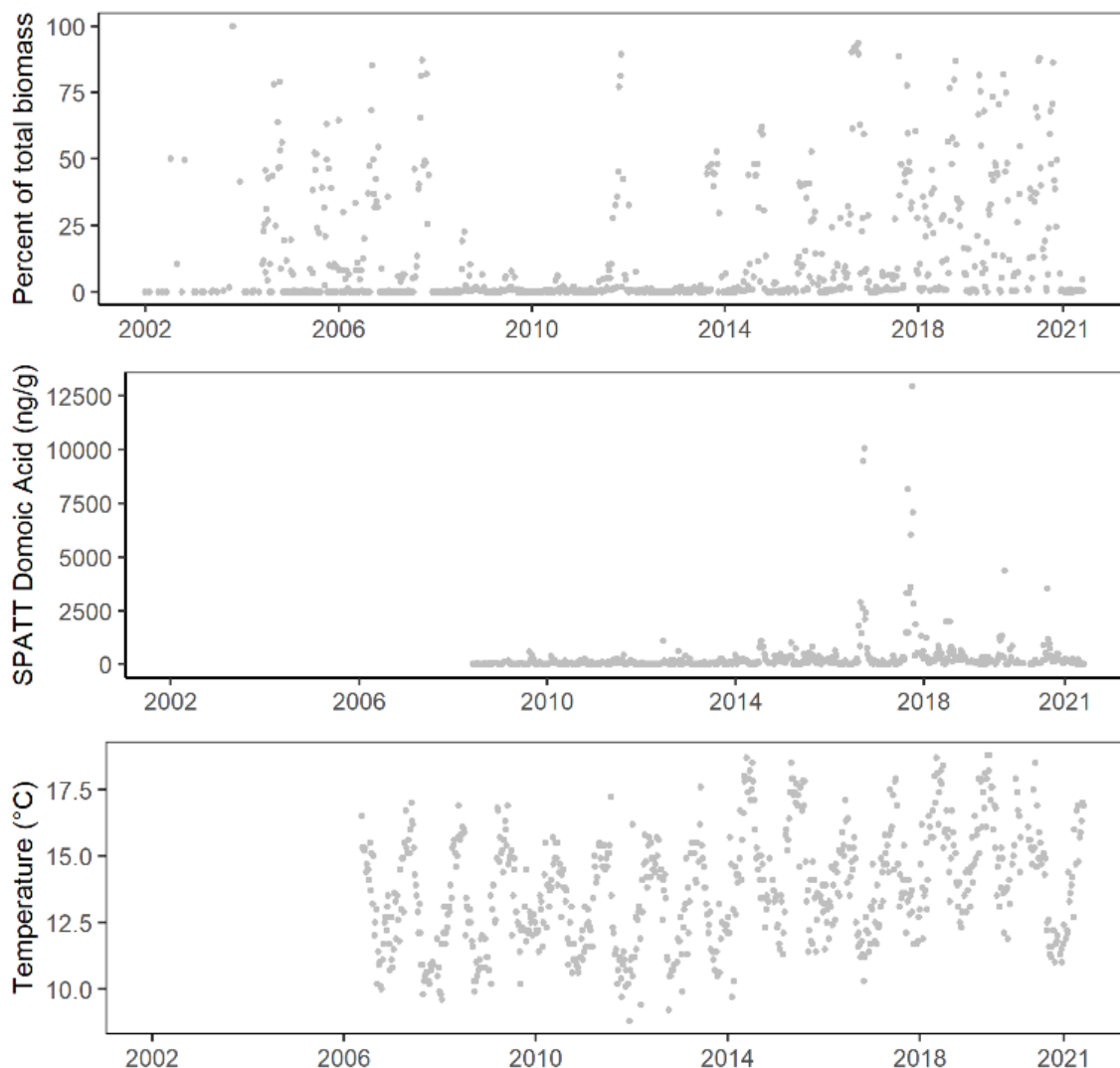


concentrations were lower (below 3 ng/mL) at the sites furthest north (Trinidad; note more limited data) and south (Scripps Pier). Individual peaks in *Pseudo-nitzschia* seriata size class cell counts and pDA concentrations for each monitoring site were generally concurrent, but there were some exceptions. For example, a large *Pseudo-nitzschia* seriata bloom event occurred at Cal Poly Pier in October 2011 without a corresponding peak in pDA concentrations; conversely, in October 2012 a relatively large spike in pDA concentrations was accompanied by comparatively low *Pseudo-nitzschia* seriata cell counts.

Figure 3.6.2 presents a time series for the relative abundance of specific dinoflagellate taxa, dissolved domoic acid (dDA), and sea surface temperature in Santa Cruz Wharf. Analyses indicated that both dinoflagellate abundance and dDA concentrations were positively correlated with temperature (not shown; Kudela pers. comm., 2021). These results indicate that with warming oceans, DA concentrations and dinoflagellate abundance will increase, particularly within Central and Northern California.



Figure 3.6.2. Santa Cruz Wharf



The figures show the relative abundance index of several “red tide” forming taxa combined (*Alexandrium*, *Cochlodinium*, and *Gymnodium/Akashiwo*) compared to overall total phytoplankton biomass (top panel), dDA concentrations in Solid Phase Adsorption Toxin Tracking (SPATT) (middle panel), and sea surface temperature (bottom panel) data over time at Santa Cruz Wharf. Source: HABMAP and Kudela, personal communication (2021)

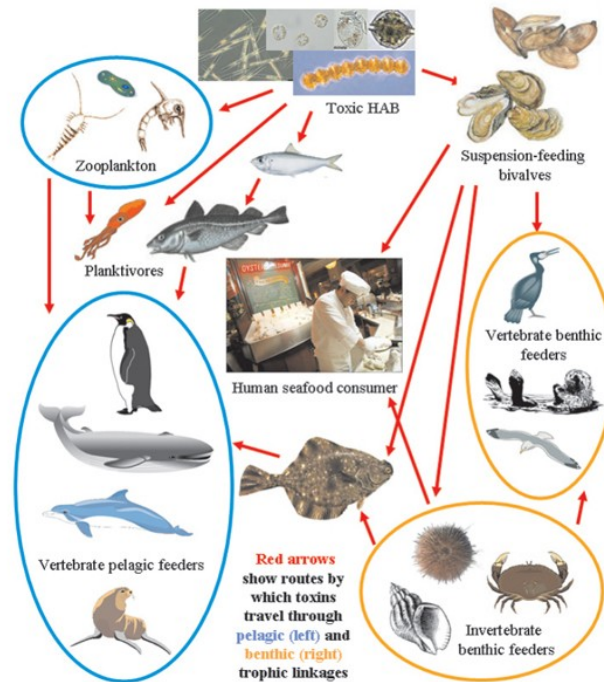
Why is this indicator important?

Marine HABs can harm marine ecosystems by producing marine biotoxins (DA and PSTs) that move up the food chain, contaminating seafood and causing illness or death in human consumers, marine mammals, and seabirds ([Figure 3.6.3](#)). Additionally,



other marine dinoflagellate “red tides” can cause fish kills, deplete oxygen, reduce light penetration, and damage seabird feathers (Skelton et al., 2024).

Figure 3.6.3. How HAB Toxins Move Up the Food Chain.



Ingestion of DA-containing *Pseudo-nitzschia* cells leads to toxin buildup in mussels, oysters, clams, and planktivorous fish (sardines, anchovies, etc.). Other species may be exposed by eating contaminated prey or sediments. Anchovies are a dominant vector. While DA can harm marine mammals and seabirds, they typically do not cause die-offs in the vector invertebrate and finfish species themselves. Source: [US National Office for Harmful Algal Blooms 2021](#)

Consumption of DA-contaminated seafood can cause Amnesic Shellfish Poisoning in humans, with symptoms ranging from gastrointestinal illness to seizures, memory loss, and even death. Current FDA regulatory standards for DA in seafood may be insufficient to protect exposed individuals at all life stages (Campbell et al., 2024) and/or across different patterns of consumption (Grattan et al., 2016). To protect the public from acute DA toxicity, fishery actions are triggered when DA in seafood samples exceed regulatory limits, leading to significant economic losses and broader social impacts in coastal communities (Hunsicker et al., 2026). Recreational bivalve shellfish fishery impacts from marine biotoxins are typically greatest and recently increasing



(2010-2024) in northern California (Smith, 2026) where the recreational razor clam fishery is located, particularly because razor clams are very slow to remove DA from their tissues compared to other bivalves (e.g., mussels).

Tribal Connection 3.6.1

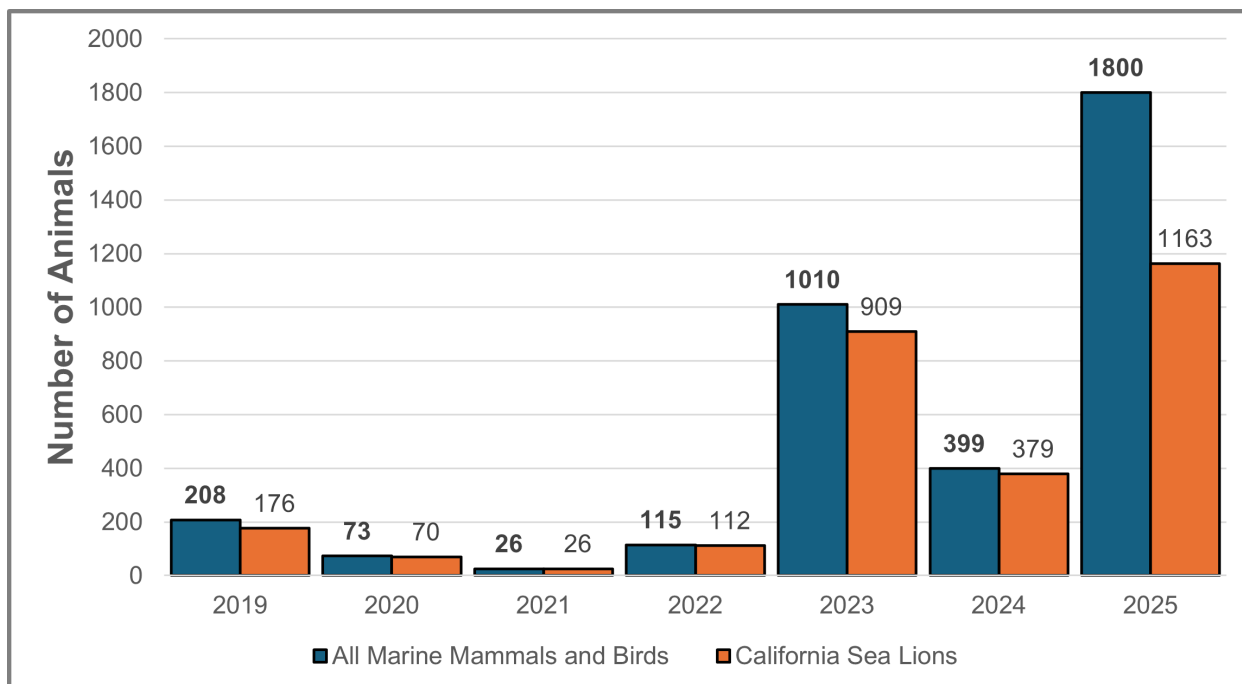
Missed catch opportunities due to HABs have far-reaching cultural impacts, beyond economics, on coastal tribes, including the Wiyot Tribe located around Humboldt Bay or *Wigi*. The Wiyot Tribe writes, “*Pseudo-nitzschia blooms off the coast of Wigi have had a particularly negative impact on the Dungeness crab and razor clam fisheries, both species that the Wiyot rely on for subsistence. [...]. Dungeness crab is fished commercially and recreationally in Humboldt County, and razor clams are fished recreationally. The Tribe has suffered cultural and economic losses as a result of missed catch and consumption opportunities of these and other species impacted by HABs. Razor clam consumption advisories or closures have been in place in Humboldt County over the majority of the past decade due to domoic acid. While there are more varied reasons for closures and restrictions in the Dungeness commercial and recreational fisheries, fishery-dependent communities around Wigi were shown to be particularly economically and socially vulnerable to the 2015-2016 domoic acid closure events (Moore et al., 2019)*” (Wiyot Tribe, 2026).

DA poisoning in California marine mammals has been documented since at least 1990, with increased occurrences observed after 1998 (Anderson et al., 2021; Scholin et al., 2000; Smith et al., 2023). Marine mammal strandings are most prominent in Southern California where the primary breeding colonies are located. From 2019-2020, reported California marine mammal and bird strandings related to DA have been tracked and submitted to CDC’s [One Health Harmful Algal Bloom System](#) (OHHABS), with California sea lions representing the majority of strandings (**Figure 3.6.4**). A major DA event developed in the Southern California Bight in early spring 2025. This event was unique in that it began earlier in the year, coinciding with early-stage pregnancy in California sea lions, lasted more than three months, and included more dolphin and whale strandings. Concurrent PST detections were also observed in some areas. This was



also the fourth year in a row that a large marine mammal stranding event was associated with a DA event in Southern California, with all events linked to upwelling conditions (Hunsicker et al., 2026).

Figure 3.6.4. Marine HAB-associated Illnesses in Mammals and Birds.



The graph shows marine HAB-associated illnesses in all marine mammals and birds (blue bars) reported to OHHABS from 2019 – 2025. California sea lions (orange bars) are also shown as a subset of all marine mammals and birds reported annually. Source: OEHHA Marine HAB-Related Illness Tracking (2026)

PSTs are produced by dinoflagellates such as *Alexandrium*, *Gymnodinium*, and *Pyrodinium*, and can accumulate in seafood. *Alexandrium* is highly toxic and can produce unsafe levels of PSTs at even relatively low cell counts and with no visible indicators (CDPH, 2021). PST exposure can cause paralytic shellfish poisoning (PSP) illness symptoms in humans ranging from numbness and gastrointestinal illness to respiratory failure and death (Anderson et al., 2021). A major 1927 outbreak near San Francisco led to over 100 illnesses, including six deaths (Price et al., 1991), leading to the establishment of the first U.S. shellfish PST monitoring program. The last major PSP



outbreak in California occurred in July 1980 with 98 illnesses and two deaths. In August 1991, 11 non-fatal PSP illnesses, including three hospitalizations, were reported for persons who had eaten mussels they had collected in northern Sonoma County. In March 2018, one non-fatal PSP illness requiring hospitalization occurred in a patient who ate mussels collected in northern Marin County. In 2025-2026, five non-fatal probable PSP cases were reported (CDPH, 2026).

California also experiences “red tides” with visibly discolored water and high biomass of other marine dinoflagellates, such as *Akashiwo sanguinea*, often occurring in warm fall conditions. Although most visible “red tides” of marine dinoflagellates are “non-toxic” (Kudela et al., 2015), people exposed to marine HABs through water contact may experience irritation of the eyes, skin, or respiratory system, even when toxins are not present.

What factors influence this indicator?

Globally, shifts in marine HABs distribution, increased abundance, and increased toxicity of marine HABs have been associated with warming conditions (Bindoff et al., 2019), along with interrelated factors such as upwelling and nutrients. While warmer water conditions generally favor marine HABs, there are some exceptions, including an apparent upper maximum temperature for some endemic strains of *Pseudo-nitzschia* (Smith et al., 2018) and cooler, nutrient-enriched water from upwelling as a positive driver for *Pseudo-nitzschia* in Monterey Bay, the Santa Barbara Channel, and the San Pedro Channel (Sandoval-Belmar et al., 2023). In typical years, water temperatures in some areas of Southern California may exceed the 20°C threshold (Smith et al., 2018), consistent with lower *Pseudo-nitzschia* seriata size class cell counts and pDA concentrations observed at Scripps Pier, and greater impacts concentrated north of Los Angeles County such as those seen during the 2015-2016 marine heatwave (McCabe et al., 2016). Modeling analyses of HAB occurrence along the southern Oregon and California coast from 1995 to 2020 (Saha et al., 2026) similarly suggests that during the spring to summer months, pDA probability decreases south of 36°N latitude (approximate latitude of Santa Cruz) and increases north of 36°N latitude, and that probability also increases during fall and winter nearshore events mainly between 36-



42°N latitude, possibly due to shifting upwelling intensity. At Stearns Wharf (Santa Barbara) and Goleta Pier, *Pseudo-nitzschia* abundance and pDA concentrations were higher during upwelling versus non-upwelling periods, but because of high variability, these relationships were not significant for the offshore stations (Umhau et al., 2018).

Ocean circulation patterns, including the Pacific Decadal Oscillation (PDO), North Pacific Gyre Oscillation (NPGO), and the two phases of the El Niño Southern Oscillation (El Niño and La Niña), may also influence marine HABs, but the responses appear to vary by region along the California coastline. Over longer time periods, increased shellfish DA concentrations in Northern California correlate with El Niño and PDO (McKibben et al., 2017), while pDA concentrations in Southern California strongly correlate with La Niña episodes (Smith et al., 2018) and negative NPGO, but are not significantly affected by PDO (Sandoval-Belmar et al., 2023). Research near Cal Poly Pier in Central California found a significant relationship between PDO and phytoplankton composition, with diatoms and dinoflagellates as the dominant phytoplankton in the fall during negative and positive PDO phases, respectively (Barth et al., 2020). While these observations suggest that further increases in sea surface temperatures may limit DA events within Southern California to the fall and winter periods, the late winter/early spring onset 2025 event demonstrated significant impacts on marine animals. The forthcoming 2026-2027 El Niño may replicate conditions similar to the 2015-2016 DA event (NOAA, 2026) with potentially significant impacts to marine life and fisheries.

Nutrient inputs from natural upwelling events and anthropogenic sources (including urban runoff) play a role in marine HABs. In southern California, terrestrial nitrogen input enhanced coastal diatom production. Surface pDA along the coast increased on average by 25% with anthropogenic inputs (Sandoval-Belmar et al., 2026). Silicate and phosphorus limitations are consistently correlated with pDA (Smith et al., 2018). A change in the silica concentrations within upwelling waters of Southern California was associated with an increase in *Pseudo-nitzschia* bloom frequency (Bograd et al., 2015) and with the NPGO. Kudela et al. (2003) looked at the correlation between nutrient runoff and *Pseudo-nitzschia* bloom events in Monterey Bay and did not find a relationship between the two. Lane et al. (2009) developed several models for *Pseudo-*



nitzschia in Monterey Bay and identified that Pajaro River discharge was a key negative factor in the Fall-Winter model, meaning discharge resulted in fewer fall blooms. However, Kudela et al. (2008) suggests that urea may be a key variable in bloom events associated with runoff; higher urea concentrations at the Santa Cruz Wharf correlate with higher *Pseudo-nitzschia* abundance. Urea is not often measured in water quality samples, and the lack of these data may have limited previous studies in California from identifying a positive correlation between nutrient runoff and blooms.

Dinoflagellates respond differently to these factors and, at the event scale, dinoflagellate blooms are primarily driven by changes in the intensity and direction of local winds (Fischer et al., 2020). It is unclear whether long-term increases in temperature and upwelling intensity will favor or inhibit dinoflagellate blooms overall, particularly because inter-annual variability is the dominant pattern in this record (Fischer et al., 2020; Smith et al., 2018).

Technical considerations

Data characteristics

Phytoplankton and pDA data were obtained via the [Environmental Research Division's Data Access Program \(ERDDAP\)](#) in March 2026. SPATT dDA data for Santa Cruz was obtained from Dr. Kudela in 2021. Weekly phytoplankton samples are collected by the [Harmful Algal Bloom Monitoring and Alert Program \(HABMAP\)](#) at nine pier locations throughout California; seven of these stations have historical data. In addition to phytoplankton, water quality samples are taken to measure marine biotoxins, temperature, salinity, and nutrients. Surface water samples were taken from each station and a 100-mL water sample preserved to analyze phytoplankton abundance. To calculate the relative abundance index, the Utermöhl method was used to subset the sample and count phytoplankton under a dissecting microscope. Relative abundance was calculated by looking at the abundance of the general compared to the total phytoplankton population (Barth et al., 2020). The relative abundance is then reported as: (1) none; (2) rare, less than 1% (3) present, 1 to 9%; (4) common, 10 to 49%; and (5) abundant, greater than 50% (Radan, 2021).



Strengths and limitations of the data

The HABMAP nearshore station data included above are robust, collected at consistent intervals, and with similar methods since 2008, providing a valuable time series dataset for those areas that are publicly available. The limited publicly available pDA data for Trinidad Pier makes it difficult to analyze trends in that region. Furthermore, these nearshore, surface water data may not be representative of what is happening offshore or in deeper waters. Umhau et al. (2018) found that offshore stations often had higher DA concentrations than nearshore stations. These near-shore data do not always correspond with risk predictions by California-Harmful Algae Risk Mapping (C-HARM) that utilizes simulations of the physical circulation using a Regional Ocean Model System (ROMS) to predict water temperature, salinity, upwelling, advection. C-HARM output may be more closely correlated with marine mammals that strand along the coast due to DA toxicosis (Anderson et al., 2016).

As noted above, the *Pseudo-nitzschia* abundances are typically reported as two size classes (not individual species) due to the lack of microscopic species-specific identifiers. Future availability of rapid, low-cost genetic identification of *Pseudo-nitzschia* species may inform potential relationships between individual *Pseudo-nitzschia* species abundance and DA concentrations, and how these are impacted by changes in environmental conditions, such as temperature fluctuations and nutrient composition (Lema et al., 2019).



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