The Variability of *Pseudo-nitzschia* and Domoic Acid along the U.S. West Coast

Steffaney Wood (stwood@davidson.edu);[1] David Backus, PhD;[1] Brian D. Bill, MSc;[2] Vera L. Trainer, PhD[2]
[1]Department of Environmental Studies, Davidson College, Davidson, NC 28035;
[2]NOAA Northwest Fisheries Science Center, Seattle, WA 98112

Abstract

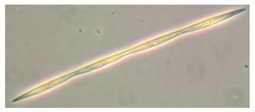
Since the occurrence of a massive, destructive harmful algal bloom (HAB) along the U.S. West Coast in 2015, the variability in the occurrence of toxigenic planktonic diatom *Pseudo-nitzschia* has posed a threat to fisheries, marine mammal survival, and public health. Certain species of the genus *Pseudo-nitzschia* produce the neurotoxin domoic acid (DA), which can cause amnesic shellfish poisoning (ASP) in humans who consume shellfish contaminated with this toxin. The objectives of the continued assessment of abundance and toxicity of *Pseudo-nitzschia*, include the identification of emerging hotspots, the investigation of *Pseudo-nitzschia* and DA occurrence relative to environmental phenomena such as El Niño and the Blob, and the synthesis of data that are incorporated into the HAB early-warning system. Seawater samples collected on the NOAA research vessel *Bell M. Shimada* in May 2017 were analyzed in the laboratory using the following methods: 1. indirect cBASI Enzyme-linked Immunosorbent Assays (ELISAs) to determine DA concentration; 2. light microscopy to determine abundance of *Pseudo-nitzschia*; and 3. scanning electron microscopy to determine *Pseudo-nitzschia* species composition at select locations. Results indicated that freshwater plumes can affect the location and distribution of *Pseudo-nitzschia* at the HAB hotspot at Heceta Bank, OR and a significant correlation between upwelling and toxicity at emerging hotspot Trinidad, CA. For future analysis, nutrient and chlorophyll data will be examined. This research will add to the time series data used to determine the influence El Niño, La Niña and Pacific Decadal Oscillation on the increasing frequency of HABs along the U.S. West coast.

Objectives

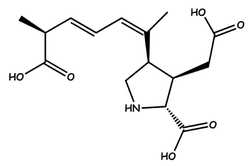
- Assess and compare the toxicity of *Pseudo-nitzschia* between 2015-2017
- Examine oceanographic features, such as upwelling, El Niño, and the Pacific Decadal Oscillation, in the context of abundance and toxicity
- Investigate the role of the Columbia River
- Determine the specific oceanographic conditions at hotspots Heceta Bank, OR and Trinidad, CA

Background

- Certain species of the genus *Pseudo-nitzschia* produce a neurotoxin called domoic acid
  - >20 toxic species of *Pseudo-nitzschia*
  - *P. australis* is the most toxic species on the west coast
- Domoic acid imitates glutamate in mammals, which can lead to nerve cell death
- In humans, intoxication with domoic acid is known as Amnesic Shellfish Poisoning
- May 2015: Most extensive domoic acid-producing harmful algal bloom on record
  - 2015-2016 El Niño
  - The Blob: Pacific Decadal Oscillation phenomenon raised temperatures up to 4˚C above normal
  - Resulting fisheries closures costed millions of dollars in economic loss for the industry
- Detection and poisoning also commonly affects marine mammals such as sea lions, harbor seals, dolphins, and whales



Pseudo-nitzschia



Domoic acid molecular structure

Pseudo-nitzschia → Krill, Sardines, Mussels, Clams → Sea Lions, Pelicans, Whales, Dolphins

Results

Abundance 2015

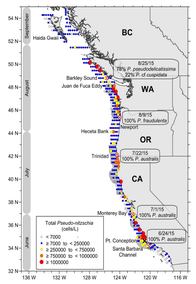


Figure 1. Abundance of 2015 mega-bloom, shows species variation to indicate toxicity. *Source NWFSC, 2015.*

Toxicity 2016

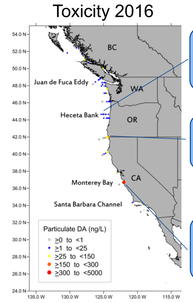


Figure 2. Toxicity of 2016 bloom, species analysis taken from 3 hotspot locations. *Source Spencer, 2016.*

84% *P. pungens*
16% *P. multiseries*

72% *P. australis*
28% *P. pungens*

78% *P. australis*
22% *P. pungens*

Toxicity 2017

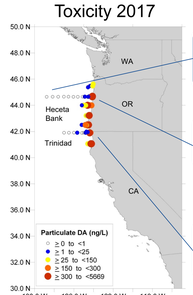


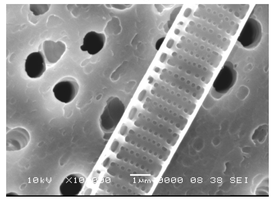
Figure 3. Toxicity of 2017 bloom, species analysis taken from 3 hotspot locations.

72% *P. pungens*
28% *P. australis*

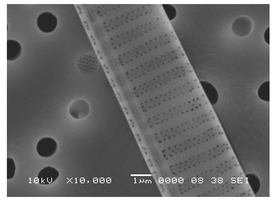
59% *P. pungens*
41% *P. australis*

75% *P. australis*
22% *P. multiseries*
3% *P. pungens*

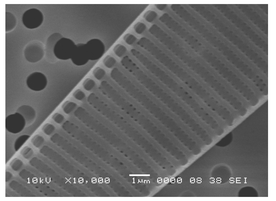
P. pungens



P. multiseries

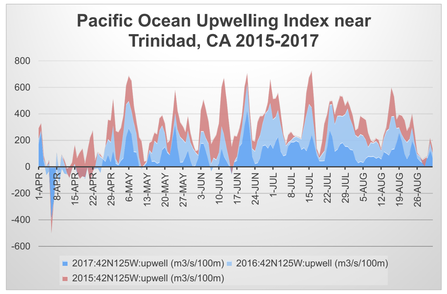


P. australis



Less Toxic ⟷ More Toxic

Figure 4. Scanning electron microscope images of *Pseudo-nitzschia* species taken at 10,000x magnification.



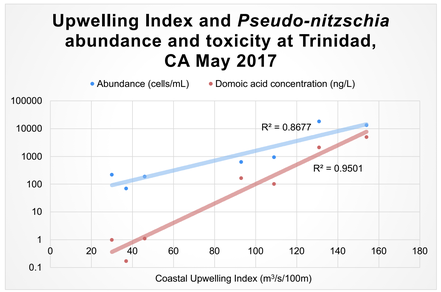
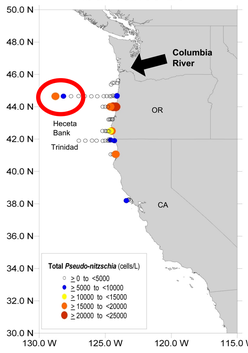
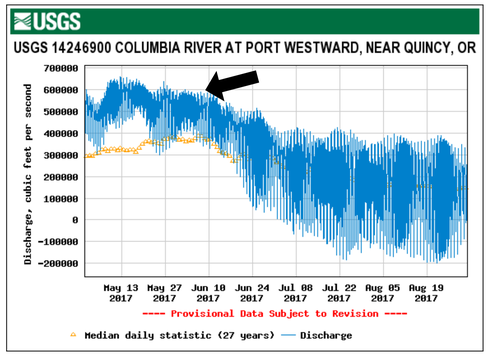


Figure 5. (Left) Graph showing decrease in upwelling between the years 2015 and 2017. *Data source "Columbia River DART," UW.*
Figure 6. (Right) Relationship of domoic acid concentration (ng/L) and *Pseudo-nitzschia* abundance (cells/mL) to upwelling index (m^3/s/100m) across 7 sampling sites near Trinidad, CA; (Assumed exponential growth rate and logarithmic scale based on limited nutrient model; Domoic acid concentration: R^2 = 0.9501, P-value = 0.035, Cellular abundance: R^2 = 0.8677, P-value = 0.039).

Abundance 2017





May SST Anomaly

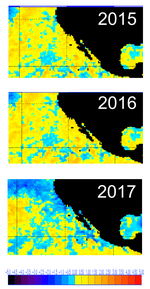
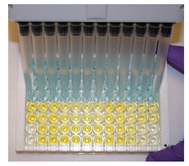


Figure 7. (Left) *Pseudo-nitzschia* abundance from May 2017, high abundance off shore corresponds with Fig. 8 data showing above average discharge from the Columbia River.
Figure 8. (Center) Columbia River discharge near the coast between May and August 2017. *Source USGS.*
Figure 9. (Right) Sea surface temperature data for May 12, 2015-2017. *Source NOAA OSPA.*

Methods

- Shipboard sampling
  - Whole water and net water samples were collected aboard the *Bell M. Shimada* sampling sites
  - Samples were filtered for particulate DA analysis, frozen for dissolved DA analysis, and formalin was added for cell counts
- Laboratory analyses
  - Enzyme-linked Immunosorbent Assays (ELISAs) to determine DA concentration
  - Light microscopy to determine *Pseudo-nitzschia* abundance and scanning electron microscopy (SEM) to determine species at select locations
  - Analysis of oceanographic data from USGS, NOAA, and UW—including temperature, salinity, Columbia River discharge, and upwelling—using RStudio



Discussion

- Abundance and toxicity not necessarily correlated
  - Varying toxicity of different species
  - *P. australis* most abundant at highly toxic locations—tends to favor warmer temperatures
  - *P. pungens* most abundant at minimally toxic locations
- Salinity and the Columbia River
  - Freshwater plumes affect the location but not abundance of *Pseudo-nitzschia*
  - In 2017, Columbia River plume pushed an area of high abundance off shore, likely due to the Columbia River's above average discharge in May
- Initiation sites for *Pseudo-nitzschia* blooms
  - New hotspot: Trinidad, CA
  - Annual hotspot: Heceta Bank, OR
- Upwelling had significant impact on the abundance and toxicity near newly-identified hotspot off the shore of Trinidad, CA (p-value = 0.039, 0.035)
- Temperature at the time of sampling did not vary significantly between the years 2015-2017; however, upwelling generally decreased

P. multiseries

Conclusions

- Locations with high concentrations of domoic acid depend on the distribution and abundance of specific species
  - Highly toxic species, such as *P. multiseries* and *P. australis*, can create highly toxic locations with relatively low abundance
  - Minimally toxic species *P. pungens* can create areas of high abundance and low toxicity
- Salinity and the Columbia River
  - Freshwater plumes do not directly impact abundance, but can affect the location and distribution of *Pseudo-nitzschia*
- Persistence of hotspot locations for *Pseudo-nitzschia* blooms
  - New hotspot: Trinidad, CA
  - Annual hotspot: Heceta Bank, OR
- A significant correlation may exist between upwelling, abundance, and toxicity at hotspot locations, as seen at Trinidad, CA during May 2017

Acknowledgments

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