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Midlatitude Marine Heatwaves: Forcing and Impacts

Key Points:
- The 2015 U.S. West Coast wide toxic *Pseudo-nitzschia australis* bloom was facilitated by anomalous ocean conditions
- The seasonal transition to upwelling provided nutrients for the bloom, and spring storms delivered toxic cells to the nearshore environment
- West Coast toxic *Pseudo-nitzschia* events are triggered by warm anomalies associated with El Niño and the Pacific Decadal Oscillation

Supporting Information:
- Supporting Information S1

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An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions

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Abstract A coastwide bloom of the toxigenic diatom *Pseudo-nitzschia* in spring 2015 resulted in the largest recorded outbreak of the neurotoxin, domoic acid, along the North American west coast. Elevated toxins were measured in numerous stranded marine mammals and resulted in geographically extensive and prolonged closures of razor clam, rock crab, and Dungeness crab fisheries. We demonstrate that this outbreak was initiated by anomalously warm ocean conditions. *Pseudo-nitzschia australis* thrived north of its typical range in the warm, nutrient-poor water that spanned the northeast Pacific in early 2015. The seasonal transition to upwelling provided the nutrients necessary for a large-scale bloom; a series of spring storms delivered the bloom to the coast. Laboratory and field experiments confirming maximum growth rates with elevated temperatures and enhanced toxin production with nutrient enrichment, together with a retrospective analysis of toxic events, demonstrate the potential for similarly devastating ecological and economic disruptions in the future.

1. An Unprecedented Coastwide Toxic Algal Bloom

Record-breaking concentrations of the marine neurotoxin, domoic acid (DA) in 2015 caused unprecedented widespread closures of commercial and recreational shellfish and finfish fisheries and contributed to the stranding of numerous marine mammals along the U.S. West Coast (Figure 1). Several species of the marine diatom, *Pseudo-nitzschia*, many of which produce DA, have been responsible for toxic blooms around the world [*Lelong et al.*, 2012; *Trainer et al.*, 2012]. The toxin is transferred through marine food webs by ingestion of live, dying, or dead *Pseudo-nitzschia* cells by pelagic and benthic organisms and sickens or kills marine mammals and sea birds, as well as humans who ingest contaminated fish, shellfish, or crustaceans [*Lefebvre et al.*, 2002]. Seafood contaminated with DA cause symptoms in humans ranging from mild gastrointestinal distress to seizures, coma, permanent short-term memory loss, and death [*Perl et al.*, 1990].

Seasonal blooms of *Pseudo-nitzschia* are common along the U.S. West Coast. Past toxic events have been attributed to a number of different species of this genus [*Trainer et al.*, 2012]. Analyses of DA outbreaks over the last two decades have identified regional initiation "hotspots" where blooms either develop or become concentrated. These source zones tend to coincide with retentive flow patterns, such as those associated with seasonal eddies [*Trainer et al.*, 2002], over submarine banks [*Hickey et al.*, 2013], or in the lee of coastal capes [*Graham et al.*, 1992; *Trainer et al.*, 2000]. Toxic blooms off central and southern California are generally due to *P. australis* [*Scholin et al.*, 2000; *Sekula-Wood et al.*, 2011] whereas toxic spring blooms off Washington and Oregon are rarely caused by *P. australis* and, instead, are attributed to several different species [*Trainer and Suddleson*, 2005; *Trainer et al.*, 2009]. Here we show that the highly toxic species, *P. australis*, bloomed simultaneously along the west coast of the U.S. and Canada in spring 2015. This extensive bloom was a consequence of three sequential factors: the onset of seasonal upwelling, followed by a series of late spring storms and the northward transport of the toxin-producing *P. australis* at a time of anomalously high surface temperatures throughout the northeast Pacific. Refer to the supporting information for a description of data analysis methods used herein.