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Harmful algal blooms along the North American west coast region: History, trends, causes, and impacts

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ABSTRACT

Along the Pacific coast of North America, from Alaska to Mexico, harmful algal blooms (HABs) have caused losses to natural resources and coastal economies, and have resulted in human sicknesses and deaths for decades. Recent reports indicate a possible increase in their prevalence and impacts of these events on living resources over the last 10–15 years. Two types of HABs pose the most significant threat to coastal ecosystems in this "west coast" region: dinoflagellates of the genera *Alexandrium*, *Gymnodinium*, and *Pyrodinium* that cause paralytic shellfish poisoning (PSP) and diatoms of the genus *Pseudo-nitzschia* that produce domoic acid (DA), the cause of amnesic shellfish poisoning (ASP) in humans. These species extend throughout the region, while problems from other HABs (e.g., fish kills linked to raphidophytes or *Cochlodinium*, macroalgal blooms related to invasive species, sea bird deaths caused by surfactant-like proteins produced by *Akashiwo sanguinea*, hepatotoxins from *Microcystis*, diarrhetic shellfish poisoning from *Dinophysis*, and dinoflagellate-produced yessotoxins) are less prevalent but potentially expanding. This paper presents the state-of-knowledge on HABs along the west coast as a step toward meeting the need for integration of HAB outreach, research, and management efforts.

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1. Introduction

Harmful algal blooms (HABs) are a global threat to living marine resources and human health. These events impact all coastal U.S. states and large portions of coastal Canada and Mexico (Taylor, 1993; Horner et al., 1997; Mudie et al., 2002; Hernández-Becerril et al., 2007; Anderson et al., 2008b; Band-Schmidt et al., 2010). Harmful algal blooms have had significant ecological and socioeconomic impacts on Pacific coastal communities of North America for decades, and their prevalence and impacts on living resources in this west coast region have increased markedly in frequency and geographical distribution over the last 10–15 years (Anderson et al., 2008b; Kudela et al., 2008a; Kahru et al., 2009; Band-Schmidt et al., 2010; Rensel et al., 2010b; Garcia-Mendoza, unpubl. data). The HABs that threaten west coast water quality, the health of living resources, and the economies of its communities are diverse and often extend beyond jurisdictional boundaries. Comprehensive understanding of the causes and impacts of west coast HABs will therefore require a regionally integrated approach, and effective HAB management will depend on interstate and international collaboration and coordination.

Several policy drivers call for a regional approach to addressing marine problems (e.g., U.S. Commission on Ocean Policy, 2004; NOAA Program Planning and Integration, 2007; NSTC Joint Subcommittee on Ocean Science and Technology, 2007; Joint Ocean Commission Initiative, 2009). The 2004 Reauthorization of the Harmful Algal Bloom and Hypoxia Research Control Act also acknowledged the need for a regional approach to HAB research and response by establishing a procedure for requesting Regional Assessments of HABs. The U.S. Commission on Ocean Policy (2004) and the Pew Oceans Commission (2003) recommended regional ocean governance efforts as an effective mechanism to facilitate regional ecosystem assessment and management. Recognizing this need, the West Coast Governors' Agreement on Ocean Health (WCGA) was established in 2006 as a proactive, regional collaboration to protect and manage ocean and coastal resources

Table 1
Reported human illnesses and deaths due to paralytic shellfish poisonings. Additional illnesses are known from all areas, but only those associated with fatalities are reported here. Dates vary depending on state, country and when monitoring began.

Year	Cases	Deaths	Counties/areas involved	Shellfish kind
AK				
1799[1]	150+	100	Sitka, Peril Strait	Blue mussels
1934[2]	12	2	Douglas and Admiralty Islands	Not known
1944[3]	4	1	Likely Sitka	Not known
1947[4]	3	1	Peril Strait	Butter clams
1954[5]	8	1	False Pass	Blue mussels
1962[6]	27	1	Porpoise Island	Littleneck clams
1962[6]	1	1	Hawk Inlet	Blue mussels
1962[6]	1	1	Shelter Bay	Butter clams
1965[6]	4	1	Hawk Inlet	Butter clams
1994[7]	16	1	Kalsin Bay, Kodiak	Blue mussels
1997[7,8]	9	1	Sturgeon River, Kodiak	Butter clams, littleneck clams
1999[8]		1	Kodiak	Not known
2010[9]	5	2	Juneau and Haines	Cockles, Dungeness crab viscera
BC				
1793[10]	4	1	Poison Cove	Mussels, clams
1942[10]	3	3	Barkley Sound	Mussels, clams
1965[10]	4	1	Theodosia Inlet	Cockles
1980[10]	7	1	Health Harbor, Gilford Island	Butter clams
WA				
1942[11]	9	3	Sekiu, Strait of Juan de Fuca	Clams, mussels
OR				
1933[11]	21	1		
CA				
1903[12]	12	5	Sonoma County	California mussels
1927[13]	103	6	Sonoma, Marin, San Mateo	Mussels
1929[13]	60	4	Sonoma, Marin, San Mateo	Mussels, clams
1936[13]	3	2	Ventura	Mussels
1939[13]	76	8	Santa Cruz, Monterey	Mussels, clams
1943[13]	20	4	Del Norte, Humboldt	Mussels
1944[13]	12	2	San Mateo, Santa Cruz	Mussels
1946[13]	3	1	San Mateo	Mussels
1948[13]	3	1	San Mateo	Mussels
1980[13]	98	2	Sonoma, Marin	Mussels, oysters, scallops
MX				
1976[14]	7	2	Pacific Mexico	
1979–2008[15]	391	24	Pacific Mexico	
1979[16]	18	3	Mazatlan Bay, extensive fish kill	Oysters, clams
1989[14,17]	99	3	Gulf of Tehuantepec	Rocky oysters
2001–2002[17]	600	6	Michoacán and Guerrero coasts	
2001–2002[17]	101	6	Chiapas, Guerrero coasts	

Sources: AK: [1]Tikhmenev (1979), [2]Sommer and Meyer (1937), [3]Alaska's Health (1945), [4]Magnusson et al. (1951), [5]Meyers and Hillian (1955), [6]Orth et al. (1975), [7]Ostasz (2001), [8]RaLonde (2001), [9]State of Alaska Epidemiology Bulletin (2010); BC: [10]Chiang (1988); WA: [11]Nishitani and Chew (1988); OR: [11]Nishitani and Chew (1988); CA: [12]Sommer and Meyer (1937), [13]Price et al. (1991); MX: [14]Saldate-Castañeda et al. (1991), [15]Cortés-Altamirano and Sierra-Beltrán (2008), [16]Mee et al. (1986), [17]Hernández-Becerril et al. (2007).