**@.04 Marine Biotoxin Control**

**Marine Biotoxins Overview**

Shellfish are filter feeders and, therefore, can concentrate toxic phytoplankton from the water column when present in shellfish growing waters. The toxins produced by certain species of phytoplankton can cause illness and death in humans. Toxins are accumulated in the viscera and/or other tissues of shellfish and human exposure occurs when the shellfish are eaten (Gordan *et al.,* 1973). In most cases, the toxin has no effect on the shellfish itself, and toxin retention times vary by shellfish species. These toxins are not destroyed by cooking or processing and cannot be detected by taste. The presence of toxic phytoplankton in the water column or traces of their toxin in shellfish meat does not necessarily constitute a health risk, as toxicity is dependent on toxin concentration in the shellfish and amount of shellfish consumed (dose). To protect the consumer, the Authority must evaluate the concentration of toxin present in the shellfish against the levels established in the NSSP Model Ordinance to determine what action, if any, should be taken.

Toxic dinoflagellates and diatoms are single-cell marine algae that are indigenous to most coastal and estuarine waters on the Atlantic, Gulf, and Pacific coasts of America, as well as in many other parts of the world. Dinoflagellates and diatoms in their vegetative stage flourish (“bloom”) seasonally when water conditions are favorable. Blooms of these organisms can occur unexpectedly and accumulate rapidly; or may follow predictable patterns.

The relationship between red tides and biotoxin poisoning is widely misunderstood. Red tide refers to the discoloration of seawater caused by blooms of marine algae. While red tide may be related to harmful algae, it is helpful to remember that:

* Harmful algal blooms (HABs) may be other colors;
* Marine biotoxin poisoning can happen when there is no discoloration of the water; and
* Several marine algae that pose no public health risk cause water discoloration.

**Diseases and Outbreaks Overview**

All humans are susceptible to shellfish poisoning, although intoxication from commercially harvested product is extremely rare. Instead, a disproportionate number of shellfish-poisoning cases occur among tourists or others who are not native to the location where the toxic shellfish are harvested, and fishermen and recreational harvesters. This may be due to lack of awareness or disregard for either official quarantines or traditions of safe consumption.

Diagnosis of shellfish poisoning is generally based on observed symptomatology and recent dietary history. Human ingestion of contaminated shellfish results in a wide variety of symptoms, depending on the toxin(s) present, their concentrations in the shellfish, and the amount of contaminated shellfish consumed.

There are five (5) types of shellfish poisonings which are specifically addressed in the NSSP Model Ordinance: paralytic shellfish poisoning (PSP), neurotoxic shellfish poisoning (NSP), amnesic shellfish poisoning or domoic acid poisoning (ASP), diarrhetic shellfish poisoning (DSP) and azaspiracid shellfish poisoning (AZP). Of these five (5) types of shellfish poisoning, PSP, NSP and ASP are the most dangerous. PSP and ASP can cause death at sufficiently high exposures. In addition, ASP can cause lasting neurological damage. DSP and AZP cause similar symptoms mostly related to diarrhea and abdominal pain.

**Paralytic Shellfish Poisoning (PSP)** PSP is caused by saxitoxins produced by certain dinoflagellates of the genus *Alexandrium* (formerly *Gonyaulax*) and *Pyrodinium bahamense*.  Potential symptoms of PSP are numerous and can include tingling or numbness in the face, hands, and feet, weakness, slurred speech, difficulty swallowing, shortness of breath, nausea, vomiting, dizziness, headache and high blood pressure. Onset of symptoms is typically rapid (i.e. 30 minutes or less), and death from asphyxiation can occur in some cases (Etheridge 2010 and references therein).

Historically, *Alexandrium* blooms have occurred between April and December along the Pacific coast from Alaska to California and in the Northeast from the Canadian Provinces to Long Island Sound (U.S. Public Health Service, 1958), but these patterns may be evolving. The blooms generally last only a few weeks and most shellfish (except for some species of clams and scallops which retain the toxin for longer periods) clear themselves rapidly of the toxin once the bloom dissipates. Toxic blooms can occur unexpectedly or follow predictable patterns.

For example, in New England in 1972, shellfish suddenly became toxic in a previously unaffected portion of the coastline which resulted in many illnesses (Schwalm, 1973). In another case, in July 2007, a lobster fisherman harvested mussels from a floating barrel off Jonesport, Maine (an area that was open to shellfish harvesting) and he and his family ate them for dinner. All four consumers became ill with PSP symptoms and three of them were admitted to the hospital. After further investigation, it became apparent that the barrel of mussels had originated further up the coast in an area that had been banned to commercial harvest (DeGrasse, 2014).

**Neurotoxic Shellfish Poisoning (NSP) –**

From the Carolinas through the Gulf coast states, NSP is caused by brevetoxins that are primarily produced by the dinoflagellate *Karenia brevis* (formerly of the genus *Gymnodinium*). The most common public health problem associated with *Karenia* blooms is respiratory irritation; however, neurotoxic shellfish poisonings associated with *Karenia brevis* blooms have been reported in Florida (Center for Disease Control, 1973 [a] and [b]). Onset of symptoms can occur within 18 hours of exposure, although an average onset time has been noted as three to four hours following consumption (Grattan et al 2016). Gastrointestinal symptoms are commonly reported, but neurological symptoms such as numbness and tingling in the face, hands and feet, partial limb paralysis, slurred speech, loss of coordination and even reversal of hot and cold sensations have also occurred (Watkins et al 2008).

*Karenia brevis*blooms were once considered to be sporadic and seasonal, but historical records demonstrate these blooms have occurred in Florida almost annually in the years since the 1940s. They now regularly occur along the Gulf Coast between Florida and Texas, and although more frequent in late summer and early fall, Florida blooms have been documented in almost every month of the year and may disperse in a matter of weeks, or may be present for many months at a time. Occurrence and magnitude of blooms are unpredictable. If seawater is colored during a bloom, it may appear red, brown, or simply darkened and blooms are usually accompanied by fish kills and mortalities in marine mammals and sea birds (Watkins, 2008).

**Amnesic Shellfish Poisoniong (ASP)**

ASP is caused by domoic acid, which is produced by certain diatoms of the genus *Pseudo-nitzschia*. *Pseudo-nitzschia australis* and *Pseudo-nitzschia multiseries* are common toxin producers on the west coast and in the Northeast while members of the *Pseudo-nitzschia pseudodelicatissima-*complexare common toxin producers in the Gulf of Mexico. However, there are multiple potential toxic species in eachregion and *Pseudo-nitzschia cuspidata* has resulted in at least one (1) west coast and one (1) Bay of Fundy closure.

Acute exposure to domoic acid can cause nausea, diarrhea, headaches, confusion/disorientation, seizures, and most severely, permanent short-term memory loss, coma, or death (Lefebvre and Robertson 2010, Shumway et al 2018). Onset of these symptoms can occur within 24 to 48 hours of consumption (Perl et al 1990, Grattan et al 2016). The effects of chronic, low-level exposure to domoic acid through shellfish consumption are still being studied, but potential impacts include impairment of fetal development, memory deficits, and kidney damage (Grattan et al. 2018 and Funk et al. 2014).

The factors which influence domoic acid production are not well understood but may include irradiance levels, photoperiod length, salinity, trace metals including iron and copper, the presence of marine bacteria, and decreased or halting cellular growth (Doucette et al. 2008, Lelong et al. 2014, Cusack et al. 2002). Nutrient limitations are suggested to influence species diversity which, at times, may favor toxin-producing species but studies are also underway to determine if nutrient limitations may influence domoic acid production (Thorel et al. 2017).

Blooms of *Pseudo-nitzschia* are of varying intensity, duration and extent. During a 1991-1992 incident in Washington and a 2015 event on the west coast from Washington to California, high toxin levels persisted for several years (Liston, 1994; McCabe et al. 2016). There was also an extensive event in the Northeast from Maine to Rhode Island in 2016, with different regions showing varying toxicity and species dominance within the event. The event started in late September in eastern Maine and ended in October; however, Rhode Island experienced another bloom in February of 2017.

**Diarrhetic Shellfish Poisoning (DSP)**

**Diarrhetic Shellfish Poisoning (DSP) is caused by okadaic acid and related congeners (e.g., dinophysis toxins) produced primarily by dinoflagellates of the genus *Dinophysis*. Typical symptoms of DSP include abdominal pain, nausea and vomiting, diarrhea, headache, fever, and chills, with a short onset time and symptoms lasting up to three days (Lloyd 2013, US National Office for HABs 2019). Eight *Dinophysis* species known to occur in U.S. waters, including *D. acuminata, D. acuta, D. caudata, D. fortii, D. norvegica, D. ovum, D. sacculus*, and *D. tripos*, as well as the dinoflagellate *Prorocentrum lima* and two species of *Phalacroma* (*P. rotundatum* and *P. mitra*) are all known to produce toxins (Reguera et al 2014). All eight *Dinophysis* species are present on the U.S. east coast and Gulf of Mexico, while five species (*D. acuminata, D. acuta, D. fortii, D. norvegica*, and *D. tripos*) are present on the U.S. west coast. *P. lima* and *P. rotundatum* are present in U.S. east coast, west coast, and Gulf of Mexico waters, while *P. mitra* has only been found in the Gulf of Mexico. DSP toxin profiles vary by species and strain (Anderson 2021).**

**A 2016 *Dinophysis norvegica* bloom in a Maine salt pond led to the identification of a toxin previously unknown to occur in shellfish, dihydrodinophysistoxin-1 (Deeds et al 2020). As of 2021, studies are occurring to determine the potency of the new toxin relative to regulated DSP toxins.**

**Although there have been numerous outbreaks of DSP around the world, no confirmed cases of DSP in the U.S. that were due to domestically harvested shellfish occurred prior to 2011 (Trainer 2013). A cluster of DSP illnesses, with DSP toxins confirmed in blue mussels (Mytilus edulis), occurred in Washington state in July 2011 (3 persons; Lloyd 2013) and in British Columbia, Canada in July-August 2011 (62 persons; Taylor 2013). Subsequent harvesting closures and product recalls were issued. DSP toxins have been detected at levels exceeding the FDA regulatory limit in the Eastern oyster (*Crassostrea virginica*; Texas; Campbell 2010; Deeds 2010); the Pacific oyster (*Crassostrea gigas*), varnish clam (*Nuttalia obscurata*), and manila clam (*Venerupis philippinarum*) (Washington; Trainer 2013); California mussels (*Mytilus californianus*) from Washington and Monterey Bay, CA (Trainer 2013; Schultz 2019); and various commercial and non-commercial shellfish species from New York, Massachusetts, and Maine waters (Hattenrath-Lehmann et al 2013, Deeds et al 2020,** Trainer et al. 2013  **Anderson 2021)**;  and in non-commercial shellfish in research studies in Mid-Atlantic states. (Hattenrath-Lehmann et al 2013, Wolny et al 2020, Anderson 2021).

**Azaspiracid Shellfish Poisoning (AZP)**

*Azadinium* spp. is the producer of azaspiracids, which cause AZP. Compared to the other biotoxins discussed, AZP has been much less studied globally and within the United States, with only limited monitoring data available. Azaspiracids have been detected in seawater on both the West Coast, in Washington (Puget Sound) (Trainer et al. 2013, Kim et al. 2017, Anderson et al. 2021) and the East Coast, in Virginia (Chesapeake Bay and VA coastal bays) (Onofrio et al. 2021). Harvesting closures in the U.S. have not been documented due to AZP toxins. Toxic blooms are known to occur in coastal regions of western Europe as well as northwestern Africa and eastern Canada (reference needed).

Symptoms of AZP are similar to those noted with DSP, and include nausea, vomiting, cramps, and diarrhea, with symptoms typically persisting for two to three days from onset (Furey et al 2010, Shumway et al 2018).

The first case of AZP was detected in the Netherlands in 1995, where eight people became ill after consuming mussels harvested at Killary Harbour, Ireland (McMahon and Silke 1996). From 1997 – 2000, approximately 80 individuals reported illnesses from mussels and scallops harvested from Ireland, Italy, France, and United Kingdom (Twiner, 2008). There have been no confirmed cases of AZP in the U.S. from domestically harvested product. In 2008, the first recognized outbreak of AZP in the U.S. was reported but was associated with a mussel product imported from Ireland (Klontz et al.2009).

**Marine Biotoxin Plans – Management & Contingency**

The suitability of some growing areas for shellfish harvesting is periodically influenced by the presence of marine biotoxins. The occurrence of these toxins is often unpredictable, and the potential for them to occur exists along most coastlines of the United States and other countries having shellfish sanitation Memoranda of Understanding (MOU) agreements with the United States. The unpredictability in occurrence of toxic blooms was demonstrated in New England in 1972 (Schwalm, 1973).

For this reason, even when the authority has no history or reason to expect toxin-producing phytoplankton in their growing areas, every shellfish-producing authority must have a contingency plan that defines administrative procedures, laboratory support, sample collection procedures, and patrol procedures to be

implemented on an emergency basis in the event of the occurrence of shellfish toxins. For producing authorities where there is historic occurrence of toxin-producing phytoplankton and toxicity in shellfish from their growing areas, the authority must develop a management plan for those toxin groups.

Most authorities will have a combination of management and contingency plans. Management plans are used to address those growing areas with historic occurrence of certain toxin-producing phytoplankton and contingency plans are used to address toxin-producing phytoplankton in growing areas in the event of such emergence. As an example, an authority may have statewide historical occurrence of PSP toxin-producing phytoplankton, for which it develops a management plan; however, because of a lack of illness outbreak or historical evidence of phytoplankton that produce ASP, NSP, DSP, and AZP toxins, the authority also develops a contingency plan that addresses how the authority will manage the emergence of

those toxins.

Guidance for the development of contingency and management plans is found in Section IV Guidance Documents, Chapter II Growing Areas @.02.

**Resources**

US National Office for Harmful Algal Blooms, https://Hab.whoi.edu

Food and Drug Administration, Marine Biotoxin Management V1\_2, [http](https://collaboration.fda.gov/biotoxins/?utm_campaign=Seafood%20Safety%20Update%20-%20Marine%20Biotoxin%20Video&utm_medium=email&utm_source=Eloqua&elqTrackId=de384479b4e8416997f078b1277d4578&elq=1490ef718610409f8e18efc0b8677a1c&elqaid=6833&elqat=1&elqCampaignId=5608)[s://collaboration.fda.gov/biotoxins](https://interstateshellfishsanitationconferences.my.webex.com/interstateshellfishsanitationconferences.my-en/url.php?frompanel=false&gourl=https%3A%2F%2Fcollaboration.fda.gov%2Fbiotoxins" \t "_blank)[/?elq=f3a546ff4e224fca89660b1cf26461f9&elqCampaignId=5608&elqTrackId=de384479b4e8416997f078b1277d4578&elqaid=6833&elqat=1&utm\_campaign=Seafood+Safety+Update+-+Marine+Biotoxin+Video&utm\_medium=email&utm\_source=govdelivery](https://collaboration.fda.gov/biotoxins/?utm_campaign=Seafood%20Safety%20Update%20-%20Marine%20Biotoxin%20Video&utm_medium=email&utm_source=Eloqua&elqTrackId=de384479b4e8416997f078b1277d4578&elq=1490ef718610409f8e18efc0b8677a1c&elqaid=6833&elqat=1&elqCampaignId=5608)

### [https://www2.whoi.edu/site/andersonlab](https://interstateshellfishsanitationconferences.my.webex.com/interstateshellfishsanitationconferences.my-en/url.php?frompanel=false&gourl=https%3A%2F%2Fwww2.whoi.edu%2Fsite%2Fandersonlab" \t "_blank)/

**References**

Centers for Disease Control (a). 1973. Shellfish Poisoning - Florida. *Morbid. Mortal. Weekly Rep*. 22(48):397-398.

Centers for Disease Control (b). 1973. Neurotoxic Shellfish Poisoning - Florida. *Morbid. Mortal. Weekly Rep*. 22(48):397-398.

Deeds, J.R., & Landsberg, J.H., Etheridge, S.M., Pitcher, G.C., Longan, S.W. (2008). Non-traditional vectors for paralytic shellfish poisoning. *Marine Drugs, 6(2)*, 308-348. Retrieved from <https://doi.org/10.3390/md6020308>.

Degrasse, S., & Rivera, V., Roach, J., White, K., Callahan, J., Couture, D., Simone K., Peredy, T., Poli, M. (2014). Paralytic shellfish toxins in clinical matrices extension of AOAC official method 2005.06 to human urine and serum and application to a 2007 case study in Maine. Deep Sea Research Part II: Topical Studies in Oceanography, 103, 368-375. Retrieved from https://doi.org/10.1016/j.dsr2.2012.08.001.

Food and Drug Administration. 1977. Poisonous or Deleterious Substances in Food. *Federal Register* 42(190):52814-52819.

Food and Drug Administration. 1985. Action Levels For Poisonous or Deleterious Substances in Human Food and Animal Feed. U.S. Department of Health and Human Services, Public Health Service, Washington, D.C. 20204. 13 pages.

Gordon, K., M.D., *et al*. 1973. Shellfish Poisoning. *Morbid. Mortal. Weekly Rep*. 22, (48):397- 398.

Klontz, K.C., & Abraham, A., Plakas, S., Dickey, R. (2009). Mussel-associated azaspiracid intoxication in the United States. Annals of Internal Medicine, 150(5), 361. Retrieved from <https://www.researchgate.net/publication/24174858_Mussel-> Associated\_Azaspiracid\_Intoxication\_in\_the\_United\_States

Liston, J. (1994). Association of Vibrionaceae, natural toxins, and parasites with fecal indicators, p. 215-216. In Hackney, C.R. and M.D. Pierson (eds.). Environmental Indicators and Shellfish Safety. Chapman and Hall, New York, NY.

Lloyd, J.K., & Duchin, J., Borchert, J., Quintana, H.F., Robertson, A. (2013). Diarrhetic Shellfish Poisoning, Washington, USA, 2011. Emerging Infectious Diseases 19(8), 1314-1316. Retrieved from <https://doi.org/10.3201/eid1908.121824>.

McCabe, R.M., & Hickey, B.M., Kudela, R.M., Lefebvre, K.A., Adams, N.G., Bill B.D., Gulland, F.M.D., Thomson, R.E., Cochlan, W.P., Trainer, V.L. (2016) An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. Geophysical Research Letters, 43(19), 10,366–10,376. Retrieved from [https://DOI.org/10.1002/2016GL070023](https://doi.org/10.1002/2016GL070023).

Schwalm, D.J. (1973). The 1972 PSP outbreak in New England. FDA Report, Boston, MA. U.S. Food and Drug Administration, Washington, D.C.

Trainer, V.L., & Moore, L., Bill, B.D., Adams, N.G., Harrington, N., Borchert, J., da Silva, D.A.M., Eberhard, B.T.L. (2013). Diarrhetic shellfish toxins and other lipophilic toxins of human health concern in Washington State. Marine Drugs, 11, 1815–1835. Retrieved from <https://doi.org/10.3390/md11061815>.

Twiner, M.J., & Rehmann, N., Hess, P., Doucette G.J. (2008). Azaspiracid shellfish poisoning: a review on the chemistry, ecology, and toxicology with an emphasis on human health impacts. Marine Drugs, 6(2), 39-72. Retrieved from <https://doi.org/10.3390/md6020039>.

US Public Health Service (PHS). (1958). Proceedings: 1957 Conference on Shellfish Poison. U.S. PHS, Washington, D.C. 125 pages. Retrieved from <https://babel.hathitrust.org/cgi/pt?id=uc1.31822005678131&view=1up&seq=>

Watkins, S.M., & Reich, A., Fleming, L.E., Hammond, R. (2008). Neurotoxic shellfish poisoning. Marine Drugs, 6(3), 431-455. Retrieved from: <https://doi.org/10.3390/md6030431>.

Anderson, 2021 h[ttps://www.sciencedirect.com/science/article/pii/S1568988321000020](https://interstateshellfishsanitationconferences.my.webex.com/interstateshellfishsanitationconferences.my-en/url.php?frompanel=false&gourl=https%3A%2F%2Fwww.sciencedirect.com%2Fscience%2Farticle%2Fpii%2FS1568988321000020)

Cusack, C., Bates, S., Quilliam, M., Patching, J., Raine, R. (2002). Confirmation of domoic acid production by Pseudo-nitzschia australis (Bacillariophyceae) isolated from Irish waters. Journal of Phycology, 38, 1106-1112.

Doucette, G., King, K., Thessen, A., Dortch, Q. (2008). The effect of salinity on domoic acid production by the diatom Pseudo-nitzschia multiseries. Retrieved from <https://www.researchgate.net/publication/216802531_The_effect_of_salinity_on_domoic_acid_production_by_the_diatom_Pseudo-nitzschia_multiseries>.

Funk, J., Janech, M., Dillon, J., Bissler, J., Siroky, B., Bell, P. (2014). Characterization of renal toxicity in mice administered the marine biotoxin domoic acid. Journal of the American Society of Nephrology, 25(6), 1187-1197.

Grattan, L., Boushey, C., Liang, Y., Lefebvre, K., Castellon, L., Roberts, K., Toben, A. Morris, J. (2018). Repeated dietary exposure to low levels of domoic acid and problems with everyday memory: research to public health outreach. Toxins (Basel), 10(3), 103.

Lelong, A., Hegaret, H., Soudant, P. (2014). Link between domoic acid production and cell physiology after exchange of bacterial communities between toxic Pseudo-nitzschia multiseries and non-toxic Pseudo-nitzschia delicatissima. Marine Drugs, 12(6), 3587-3607.

Thorel, M., Claquin, P., Schapira, M., Le Gendre, R., Riou, P., Goux, D., Le Roy, B., Raimbault, V., Deton-Cabanillas, A., Bazin, P., Kientz-Bouchart, V., Fauchot, J. (2017). Nutrient ratios influence variability in Pseudo-nitzschia species diversity and particulate domoic acid production in the Bay of Seine (France). Harmful Algae, 68, 192-205.

Anderson DM, Fensin E, Gobler CJ, Hoeglund AE, Hubbard KA, Kulis DM, Landsberg JH, Lefebvre KA, Provoost P, Richlen MR, Smith JL, Solow AR, Trainer VL. Marine harmful algal blooms (HABs) in the United States: History, current status and future trends. Harmful Algae. 2021;102: Article 101975.

Deeds JR, Stutts WL, Celiz MD, MacLeod J, Hamilton AE, Lewis BJ, Miller DW, Kanwit K, Smith JL, Kulis DM, McCarron P, Rauschenberg CD, Burnell CA, Archer SD, Borchert J, Lankford SK. Dihydrodinophysistoxin-1 Produced by Dinophysis norvegica in the Gulf of Maine, USA and Its Accumulation in Shellfish. Toxins. 2020; 12(9):533.

Hattenrath-Lehmann TK, Marcoval MA, Berry DL, Fire S, Wang Z, Morton SL, Gobler CJ. The emergence of Dinophysis acuminata blooms and DSP toxins in shellfish in New York waters. Harmful Algae. 2013; 26: 33-44.

Lloyd JK, Duchin JS, Borchert J, Flores Quintana H, Robertson A. Diarrhetic shellfish poisoning, Washington, USA, 2011. Emerg Infect Dis [Internet]. 2013 Aug [date cited]. http://dx.doi.org/10.3201/eid1908.121824

Reguera B, Riobo P, Rodriguez F, Diaz PA, Pizarro G, Paz B, Franco JM, Blanco J. Dinophysis toxins: causative organisms, distribution and fate in shellfish. Marine Drugs. 2014; 12: 394-461.

Taylor M, McIntyre L, Ritson M, Stone J, Bronson R, Bitzikos O, et al. Outbreak of diarrhetic shellfish poisoning associated with mussels, British Columbia, Canada. Mar Drugs. 2013;11:1669–76.

United States National Office for Harmful Algal Blooms. Diarrhetic Shellfish Poisoning. 2019, https://hab.whoi.edu/impacts/impacts-human-health/human-health-diarrhetic-shellfish-poisoning/. Accessed 2 September 2021.

Wolny JL, Egerton TA, Handy SM, Stutts WL, Smith, JL, Whereat EB, Bachvaroff TR, Henrichs DW, Campbell L, Deeds JR. Characterization of Dinophysis spp. From the Mid-Atlantic region of the United States. Journal of Phycology. 2020; 56: 404-424.

•Trainer, V.L., Moore, L., Bill, B.D., Adams, N.G., Harrington, N., Borchert, J., Da Silva, D.A., Eberhart, B.T.L., 2013. Diarrhetic shellfish toxins and other lipophilic toxins of human health concern in Washington State. Mar. Drugs. 11 (6), 1815–1835.

Kim, J.H., Tillmann, U., Adams, N.G., Krock, B., Stutts, W.L., Deeds, J.R., Han, M.S.,Trainer, V.L., 2017. Identification of Azadinium species and a new azaspiracid from Azadinium poporum in Puget Sound, Washington State, USA. Harmful Algae 68, 152–167.

Onofrio, M.D., Egerton, T.A., Reece, K.S., Pease, S.K., Sanderson, M.P., Jones III, W., Yeargan, E., Roach, A., DeMent, C., Wood, A. and Reay, W.G., 2021. Spatiotemporal distribution of phycotoxins and their co-occurrence within nearshore waters. Harmful Algae, 103, p.101993.

McMahon, T. and J. Silke. 1996. West Coast of Ireland; winter toxicity of unknown aetiology in mussels. Harmful Algae News, 14:2.