PICES S-HAB: Country report for Canada, Sept. 2021-Aug. 2022

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1. New peer-reviewed publications and conference presentations

Publications

Boivin-Rioux A, Starr M, Chassé J, Scarratt M, Perrie W, Long Z, Lavoie D. Harmful algae and climate change on the Canadian East Coast: Exploring occurrence predictions of Dinophysis acuminata, D. norvegica, and Pseudo-nitzschia seriata. Harmful Algae. 2022 Feb 1;112:102183.

- Based on 24 years of monitoring data, a model was developed for *Dinophysis acuminata*, *D. norvegica*, and *Pseudo-nitzschia seriata*. All three species are predicted to shift their spatiotemporal occurrences during the 21st century.

Emam M, Caballero-Solares A, Xue X, Umasuthan N, Milligan B, Taylor RG, Balder R, Rise ML. Gill and Liver Transcript Expression Changes Associated With Gill Damage in Atlantic Salmon (Salmo salar). Frontiers in Immunology. 2022;13.

- Following exposure to harmful algal blooms, gill and liver samples from farmed salmon were analyzed for biomarker genes associated with tissue damage. Up- and down-regulation of specific biomarkers (e.g. wound healing, stress-response, apoptosis, blood coagulation, transcription regulation) was observed, and was generally correlated with tissues damage.

Esenkulova S, Neville C, DiCicco E, Pearsall I. Indications that algal blooms may affect wild salmon in a similar way as farmed salmon. Harmful Algae. 2022 Oct 1;118:102310.

- Based on a limited number of wild juvenile salmon samples, analyzed following exposure to harmful algal blooms, histopathological evidence (gill damage, liver apoptosis) was found indicating that HABs may directly affect wild salmon.

Esenkulova S, Suchy KD, Pawlowicz R, Costa M, Pearsall IA. Harmful Algae and Oceanographic Conditions in the Strait of Georgia, Canada Based on Citizen Science Monitoring. Frontiers in Marine Science. 2021:1193.

- Based on thousands of samples collected in the Salish Sea, spatio-temporal patterns of occurrence for several harmful algae species were revealed, along with environmental drivers. Years with high levels of harmful algae were associated with negative impacts on shellfish and salmon aquaculture.

McIntyre L, Miller A, Kosatsky T. Changing trends in paralytic shellfish poisonings reflect increasing sea surface temperatures and practices of Indigenous and recreational harvesters in British Columbia, Canada. Marine drugs. 2021 Oct 14;19(10):568.

- PSP poisoning frequencies increased over 62 years in British Columbia, Canada coinciding with rising global temperatures. Ongoing collection of data on harmful algae, especially in remote indigenous communities, is recommended.

McKenzie CH, Bates SS, Martin JL, Haigh N, Howland KL, Lewis NI, Locke A, Peña A, Poulin M, Rochon A, Rourke WA. Three decades of Canadian marine harmful algal events: Phytoplankton and phycotoxins of concern to human and ecosystem health. Harmful Algae. 2021 Feb 1;102:101852.

- Harmful algal blooms occur annually on both the Atlantic and Pacific coasts of Canada, negatively impacting human and marine life. Harmful algae are may be more widespread in Canadian Arctic than previously thought. Evaluating the potential role of harmful algae as stressor on Canadian marine ecosystem is needed.

Rashidi H, Baulch H, Gill A, Bharadwaj L, Bradford L. Monitoring, managing, and communicating risk of harmful algal blooms (HABs) in recreational resources across Canada. Environmental Health Insights. 2021 May;15:11786302211014401.

- Scan on provincial and territorial government agency protocols around harmful algal blooms in Canada suggest variations in the monitoring, managing, and communicating of risk to the public. Strategies are explore for better communicating of the risks associated with HABs, creating a coherent system and inter-agency communication is suggested.

Presentations (West Coast)

Esenkulova S, Pawlowicz R, Frederickson N, Pearsall I. Oceanographic conditions and harmful algae in the Strait of Georgia, Canada – outcomes of seven years of monitoring with the citizen science program. Salish Sea Ecosystem Conference 2022.

Ross ARS, Surridge B, Hartmann H, Mueller M, Frederickson N, Esenkulova S, Pearsall I. Profiling marine biotoxins in the Salish Sea. Salish Sea Ecosystem Conference 2022.

Ross ARS, Surridge BD, Mueller M, Haque O, Hewison T, Frederickson N. Relationships between harmful algal biotoxins and environmental conditions in British Columbia coastal waters. Ocean Sciences Meeting 2022, 24 February-4 March.

Shartau R. Harmful algal toxins in coastal British Columbia and their effect on salmonids. Department of Fish and Oceans Canada Seminar 2021.

Ross ARS, Surridge BD, Hartmann H, Mueller M, Haque O, Hewison T, Frederickson N, Johnson S, Shartau R, Turcotte L, Locke A, Hennekes M, Nemcek N, Shannon H, Sastri A, Perry IA. Recent advances in measuring and predicting the occurrence and impacts of harmful algal biotoxins in British Columbia coastal waters. PICES-2021 Virtual Annual Meeting, 25-29 October.

2. A new monitoring program

Fisheries and Oceans Canada (DFO) has established a program for monitoring multiple classes of marine biotoxins (including ASP, PSP and DSP toxins) in British Columbia coastal waters, using liquid chromatography-tandem mass spectrometry (LC-MS/MS), based on collaborations with the Pacific Salmon Foundation (PSF) Citizen Science Program and partners in the BC Salmon Aquaculture Industry. The goal of this Marine Biotoxin Monitoring Program is to increase understanding of the dynamics and drivers of harmful algal blooms and associated biotoxins that can impact wild and farmed salmon and endangered marine mammal in British Columbia coastal waters. The program, which has been running since 2020, has revealed seasonal changes in biotoxin levels associated with the timing of marine algal blooms, and significant correlations between water temperature and the concentrations of several biotoxins (including domoic acid, dinophysitoxin-1, pectenotoxin-2, and the PSP toxin C1). This work will be presented during Session S9 of the PICES-2022 Annual Meeting (Ross et al. 2022).

3. HAEs on the Canadian West Coast in the past year

East coast of Vancouver Island/Salish Sea

During 2021 there were thick vivid orange blooms of *Noctiluca scintillans* (up to 3200 cells per mL) in April, *Heterocapsa triquetra* (up to 9000 cells per mL) in June, *Dictyocha* spp. (up to 150 cells per mL) in July and August, and *Rhizosolenia setigera* (up to 500 cells per mL) and *Pseudo-nitzschia* spp. (up to 1800 cells per mL) in July and August. *Alexandrium* spp. and *Dinophysis* spp. were very abundant, but there were no blooms of *Heterosigma akashiwo* (Esenkulova et al., 2022).

During 2022 there were thick blooms of *Noctiluca scintillans* (up to 1000 cells per mL) in May and August, and a mix of diatoms (*Skeletonema*, *Rhizosolenia*, *Thalassiosira*, and *Pseudo-nitzschia* spp.) in August (unpublished observations of the Citizen Science monitoring program, Pacific Salmon Foundation). Sample analysis for 2022 is ongoing.

West coast of Vancouver Island

In late summer 2021 relatively high concentrations of domoic acid (DA) were measured on the west coast of Vancouver Island, using ELISA. On August 26 a DA concentration of 427.5 pg/ml was measured at station P2, off the south-west coast of the Island, while on September 16 a very high concentration of 974.8 pg/ml was measured further north, at station LBP3. For reference, seawater concentrations above 200 pg/ml are generally regarded as a concern in terms of the potential for DA accumulation in shellfish.

Other notes

In summer, 2021, the British Columbia Centre for Disease Control is reported in the media as having diagnosed an infection by the marine bacterium *Shewanella* sp., which is apparently the first time this has occurred in BC. The man had been wading in Baynes Sound, exposing a partially healed wound to sea water several days after experiencing an injury to his leg, and subsequently developed symptoms of sepsis. Another resident of the same area had apparently been seriously ill several years earlier after washing a wound in the ocean, but the cause of that infection was not investigated.

The media report states that *Shewanella* was not previously known to be in British Columbia waters, and speculates as to a ballast water source, but Makemson et al. (1997) had previously reported the genus in Saanich Inlet sediments and BC seawater.

References

Comox Valley Record (2021) https://www.comoxvalleyrecord.com/news/denman-island-man-battles-infection-from-rare-bacteria/

Esenkulova S, Pawlowicz R, Frederickson N, Ross A, Pearsall I (2022). Spring-summer oceanographic conditions and harmful algal blooms in the Strait of Georgia 2021. In Boldt JL, et al. (Eds.) (2022) *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2021.* Canadian Technical Report of Fisheries and Aquatic Sciences 3482. https://publications.gc.ca/collections/collection_2022/mpo-dfo/Fs97-6-3482-eng.pdf

Makemson JC, et al. (1997) Shewanella woodyi sp. nov., an exclusively respiratory luminous bacterium isolated from the Alboran Sea. International Journal of Systematic and Evolutionary Microbiology 47: https://doi.org/10.1099/00207713-47-4-1034
https://www.microbiologyresearch.org/content/journal/ijsem/10.1099/00207713-47-4-1034

Ross ARS, Surridge BD, Hartmann H, Mueller M, Hennekes M, Haque O, Frederickson N, Esenkulova S, Johnson S, Turcotte L, Locke A (2022). Correlations between ocean temperature and the concentrations of harmful algal biotoxins measured in British Columbia coastal waters. PICES-2022 Annual Meeting.

China HAB Country Report 2022

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- Red tide

According to China Marine Disaster Bulletin, 58 HAB events were recorded in the coastal waters of China in 2021, covering a total area of 23277 square kilometers (Table 1). The important HAB organisms in the coastal waters of China, are as follows： *Noctiluca scintillans, Prorocentrum donghaiense, Prorocentrum minimum, Prorocentrum micans, Akashiwo sanguinea. Alexandrium catenella, Heterosigma akashiwo, Phaeocystis globosa, Gonyaulax polygramma, Chaetoceros curvisetus.* Among them, *Noctiluca scintillans* caused the most red tides (14 times).

In terms of regional distribution, the East China Sea has the largest number of red tides and the largest cumulative area, which is 26 times and 7096 square kilometers, respectively. From the distribution of coastal provinces (autonomous regions, municipalities directly under the Central government), the number of red tides in Zhejiang was the largest and the cumulative area was also the largest, with 22 times and 7084 square kilometers, respectively. In terms of seasonal pattern, the red tide was found the most in September, with 12 times. February was the month in which the largest cumulative area of red tide was found, with a total area of 6006 square kilometers. In 2021, the largest single red tide event occurred in waters west of Weizhou Island, Guangxi Zhuang Autonomous Region, with a maximum area of 6,000 square kilometers. The longest single red tide event occurred in the coastal waters of Tianjin, with a duration of 51 days, from September 1 to October 21, and a maximum area of 104 square kilometers.

Table 1 Statistics of HABs found in various sea areas in China in 2021

Sea area	Number of HAB events	Accumulated area of HABs (Km^2)
Bohai Sea	12	6882
Yellow Sea	4	3103
East China Sea	26	7096
South China Sea	16	6196
Total	58	23277

- Green tide

In 2021, green tide scale in the Yellow Sea reached a historical maximum. On June 26, the distribution area of Yellow Sea green tide was about 60,594 Km^2, covering an area of 1,746 Km^2, which was 2.3 times that of 2013, the previous largest year. The area covered by *Ulva prolifera* in 2021 in Qingdao sea area is 9 times that of 2020. From April to August in 2021, the green tide affects the Yellow Sea area of China, and its distribution area reaches the maximum of 61 898 km^2 on June 21. The maximum coverage was reached on 26 June at about 1 746 square kilometers. *Ulva prolifera* is the causative species of green tide.

Fig. 1 Prolifera green tide in the sea area of Xiaomai Island, Qingdao City

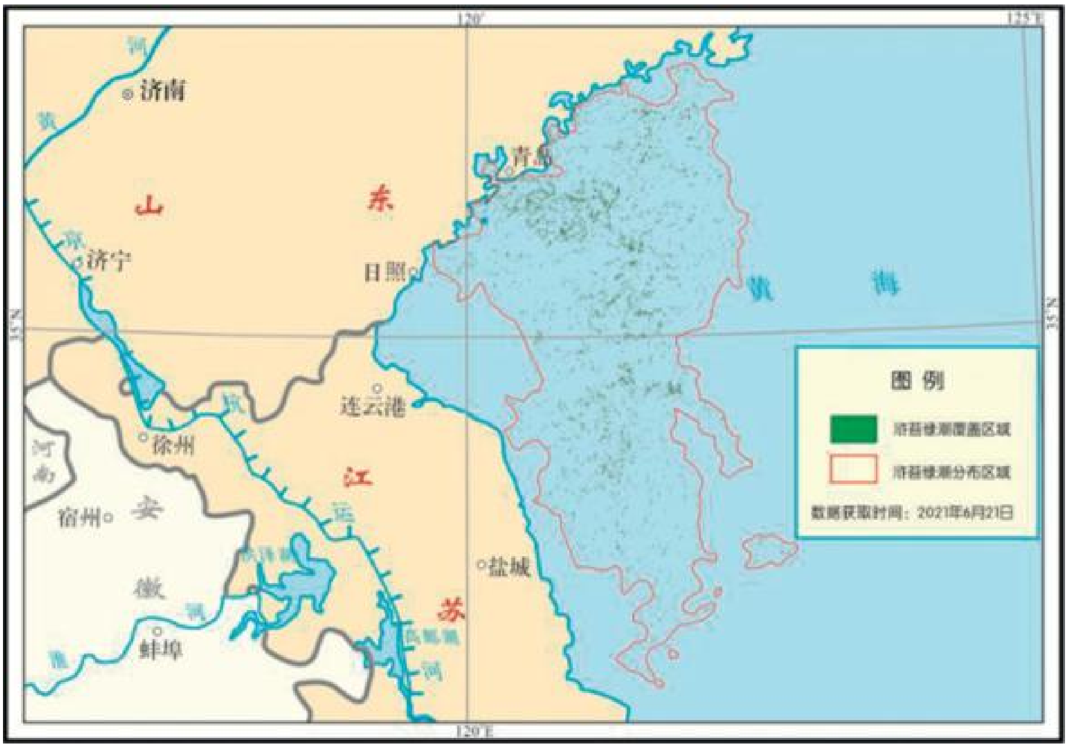

Fig. 2 Distribution pattern of green tide on June 21, 2021

PICES; Country report of Japan in 2022

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We report HABs and their associated fisheries issues in 2021–2022 (up to August 2022).

1) Long-term and recent trends of HAB events

The inter-annual variation in the blooms and the economic losses caused by HAB events have been reported over the past few decades in western Japan, such as in the Seto Inland Sea and Kyushu area. In the Seto Inland Sea, the number of blooms decreased in the 1970s–1980s and has been slowly declining in the recent decades. In the Kyushu area, the number has been on the rise overall.

2) HAB events and impacts on the fisheries in 2021

HAB events in Japan mainly take place in its western parts, such as the Seto Inland Sea and Kyushu area. Major HAB species are *Karenia mikimotoi*, *Chattonella* spp., *Cochlodinium polykrikoides*, *Heterocapsa circularisquama*, and *Heterosigma akashiwo*.

In 2021, the numbers of HAB events were 70 and 100 in the Seto Inland Sea and Kyushu area, respectively. In Hiroshima (western Seto Inland Sea), *Chattonella* spp. (maximum density; 1,009 cells/mL) killed 15,420 yellowtail (*Seriola quinqueradiata*) in mariculture, resulting in an economic loss of 26 million JPY. The bloom of *Chattonella* sp. (maximum density; 110,000 cells/mL) occurred in the Yatsushiro Sea (western Kyushu area) and killed 64,600 white trevally (*Pseudocaranx dentex*), causing 91 million JPY of damage.

In 2022, *K. mikimotoi* blooms widely occurred in western Japan. In the Yatsushiro Sea, where *Chattonella* blooms are predominant in recent years, the *K. mikimotoi* blooms have occurred (started in late July and are still ongoing as of August 26th). The blooms of *Chattonella* spp. occurred in both the Seto Inland Sea (July–August) and Kyushu area (July–August).

3) Shellfish ban by the PSP & DSP

Most of the shellfish closure caused by paralytic shellfish poisoning (PSP) and diarrhetic shellfish poisoning (DSP) occur in the southwest (Seto Inland Sea and Kyushu area) and north Pacific coast (Tohoku area and Hokkaido) of Japan. There were 48 cases of shellfish ban due to PSP in 2021. The number was down by approximately 31%, compared with that of the previous year. Shellfish species subject to the shellfish ban includes scallops, sea squirts (wild), and oysters. The causative species of PSP in 2021 were mainly *Alexandrium catenella*, *A. pacificum*, and *Gymnodinium* *catenatum.* They were mainly observed from March to June, with densities exceeding 10^4 cells/L at some sites. There were 6 cases of shellfish ban due to DSP in 2021, and the number was down by approximately 34%, compared with that of the previous year. Shellfish species subject to the shellfish ban include scallops and blue mussels. The causative species for DSP were *Dinophysis fortii* and *D. acuminata*. They were mainly observed from July to September, with densities exceeding 10^3 cells/L at some sites. While the number of the shellfish bans due to PSP and DSP have decreased compared to those of 2020, they have been on the rise in recent years, and the distribution of the toxic species has also been expanding.

4) Massive outbreak of *Karenia selliformis* on Pacific coast of eastern Hokkaido, Japan in 2021

An unprecedented large-scale harmful algal bloom occurred on the Pacific coast of eastern Hokkaido, Japan, from September to November 2021. It caused extensive fishery damage due to the deaths of sea urchins, chum salmon, fish juveniles and octopi. The damage exceeded 8 billion JPY, and subsequent research revealed that the dominant species was *Karenia selliformis*. The blooms caused by *K. mikimotoi* have been frequently reported in Japan, but it was the first time that *K. selliformis* had been observed in massive numbers in Japanese waters. The water temperature at which the cell density was high (>100 cells/mL) was in the range of 9.8–17.6 °C (Iwataki et al. 2022). Currently, multiple investigations are ongoing to understand the *K. selliformis*, including its growth physiology, and to reveal cause of the large-scale bloom (e.g., Kuroda et al. 2022).

References

Iwataki et al. 2022, Morphological variation and phylogeny of *Karenia selliformis* (Gymnodiniales, Dinophyceae) in an intensive cold-water algal bloom in eastern Hokkaido, Japan, Harmful Algae, 114, 102204. doi.org/10.1016/j.hal.2022.102204

Kuroda H, et al. 2022, Distribution of Harmful Algae (*Karenia* spp.) in October 2021 Off Southeast Hokkaido, Japan. Front. Mar. Sci. 9:841364. doi: 10.3389/fmars.2022.841364

PICES; Country report of Korea in 2022

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1. Variation in HABs in Korean coastal waters since 1970

Since the beginning of HABs monitoring in 1972, the number of HABs continued to increase from the 1980s to the 1990s. After the largest number of HAB incidents (109) in 1998; the trend declined until the 2010s. Most HABs in the 1970s were caused by diatoms. In the 1980s, coastal dinoflagellates caused HABs; *Cochlodinium polykrikoides* blooms have occurred continuously since 1993. The concentration of nutrients in coastal waters was the highest in the 1980s and was declined since the mid-1990s. This reduction in nutrient concentration is a good explanation for the decreasing number of HABs. Since 2016, a summer high water temperature of 30℃ or more has appeared, and the range and scale of *C. polykrikoides* blooms have been greatly reduced. In 2016, *K. mikimotoi* blooms occurred around Wando, Jangheung, and Goheung and small-scale blooms of *C. polykrikoides* occurred around Yeosu. There were no *C. polykrikoides* blooms in 2017; however, *Alexandrium affine* blooms occurred from Yeosu to Tongyeong. There were small-scale blooms of *C. polykrikoides* in 2018 compared to those in the previous years. Due to the long rainy season in 2020, diatom and *Ceratium furca* have dominated the water temperature and salinity was lower than the normal average. So blooms of *C. polykrikoides* in 2018 occurred in mid-October and lasted for a month. Our results show that reduction in nutrients and the high water temperature owing to climate change are good explanations for variation in HABs in Korean coastal waters.

2. Occurrence of HABs in 2021

The 11 cases of algal blooms were observed in 2021. There was a bloom of dinoflagellate *Akashiwo sanguinea* once in April and May, dinoflagellate *Noctiluca scintillans*. once in June and July, diatom *Skeletonema* sp. once in July, ciliate *Mesodinium rubrum* once in October and 3 times in November. Algal blooms were observed a total of 64 times in 2020 by *Ceratium furca* etc., but high biomass of diatoms such as *Chaetoceros* spp. and *Skeletonema* sp. were observed in ocean regions where *Cochlodinium* bloom occurred (Tongyeong ~ Goheung waters) during summer 2021.

Cochlodinium bloom in 2021 appeared at 8~320 cells/mL arround Jeollanam-do on August

9. However, tt was observed to be less than 1 cell/mL since August 14.

The bloom has occurred in a narrow range of less than 1 km. The main factor in the non-growth/spreading of *Cochlodinium* was the creation of an ecological environment unfavorable due to the continued dominance of competing organisms such as diatoms in the waters surrounding the occurrence of bloom. The unusual increase in the biomass of diatoms in the summer is the rainy season due to the late stagnant front, and frequent rainfall in the southern coastal area is identified as the largest cause.

3. Appearance of *Alexandrium* species related to PSP in 2021

Paralytic shellfish poisoning (PSP) occurs every year in Korea. Currently, countries around the world are responding sensitively to the problem of shellfish toxins in terms of public health, and are strengthening regulations such as toxin inspection and quarantine for foreign aquatic products imported into their countries.

The time of occurrence of PSP is getting faster recently, and in particular, during the outbreak of PSP in 2018, it increased and spread so fast that many fishermen missed the time to collect shellfish and suffered economic losses. In addition, as some shellfish such as mussels in circulation exceeded the paralytic shellfish toxin standard, it became a social problem. Accordingly, in Korea, the collection is prohibited depending on the concentration of shellfish toxin, and prior to this, demand for forecasting shellfish toxin according to the appearance of plankton, the cause of shellfish poisoning,

The main cause species for early (Feb – Apr 2021) PSP in Jinhae bay was *Alexandrium catenella*, and the PSP that occurred after May was *Alexandrium pacificum*. Plankton related to shellfish toxin showed a high correlation with the concentrations of dissolved inorganic nitrogen (DIN; negative) and dissolved organic nitrogen (DON; positive). A shellfish poison was detected anomalously in January 2021, which was analyzed as a result of the temporary occurrence in shellfish poison plankton due to DIN restriction by low rainfall in winter. It was confirmed that *A. catenellas* prefer low temperatures (5～20℃) for excystment and growth of vegetative cells. In other words, shellfish poison that occurs under low water temperature in Jinhae Bay is considered to be caused by *A. catenella*. On the contrary, the growth of *A. pacificum* is confirmed to mainly occur in high water temperatures (15～25℃), and their growth is limited by many factors (slow growth rate of *A. pacificum* and interspecific competition, etc.) during this period. Thus, the occurrence of shellfish poison in Jinhae Bay is expected to be more related to *A. catenella* than to *A. pacificum*. The mechanism of large-scale occurrence of shellfish poison in Jinhae Bay is summarized as follows: 1) Absorption of inorganic nitrogen flowed from rainfall by diatoms, 2) Development of low inorganic nitrogen (< 1 μM) and high organic nitrogen (> 12 μM) condition due to absorption and decomposition by diatoms. 3) Massive outbreak of shellfish poison plankton.

Country report of Russia, Jan. 2021 to Aug. 2022

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In 2021 and 2022 a monitoring survey focusing on potentially toxic species was conducted in Amur Bay off Vladivostok City (Peter the Great Bay, Sea of Japan). Several HAB events, caused by dinophyte, diatom, and raphidophyte algae, were observed (Table).

Table. List of harmful algal species recorded in Amur Bay, Jan. 2021 to Aug. 2022.

Date	Species	Maximum abundance, cells L^{-1}
Sept.–Oct. 2021	*Alexandrium pseudogonyaulax*	220×10^3
	Pseudo-nitzschia multistriata	3.4×10^6
	Pseudo-nitzschia delicatissima	1×10^6
July–Aug. 2022	*Alexandrium pseudogonyaulax*	102×10^3
	Dinophysis acuminata	3.7×10^6
	Dinophysis forthii	4×10^3
	Noctiluca scintillans	12×10^6
	Prorocentrum minimum	28×10^6
	Prorocentrum triestinum	3.7×10^6
	Scrippsiella sp.	6.2×10^6
	Heterosigma akashiwo	46.3×10^6
	Skeletonema spp. complex	60×10^6

In 2021, bloom events caused by these *Pseudo-nitzschia* species were recorded from the surface horizon in Amur Bay four times (5.6×10^5 cells L^{-1} in late August, dominated by *P. pungens*; 8×10^5 cells L^{-1} in early September, dominated by *P. calliantha*; 1.2×10^6 cells L^{-1} in late September, dominated by *P. delicatissima*; and from 5×10^5 cells L^{-1} to 3.4×10^6 cells L^{-1} during early September to early October, dominated by *P. multistriata*) (Fig. 1).

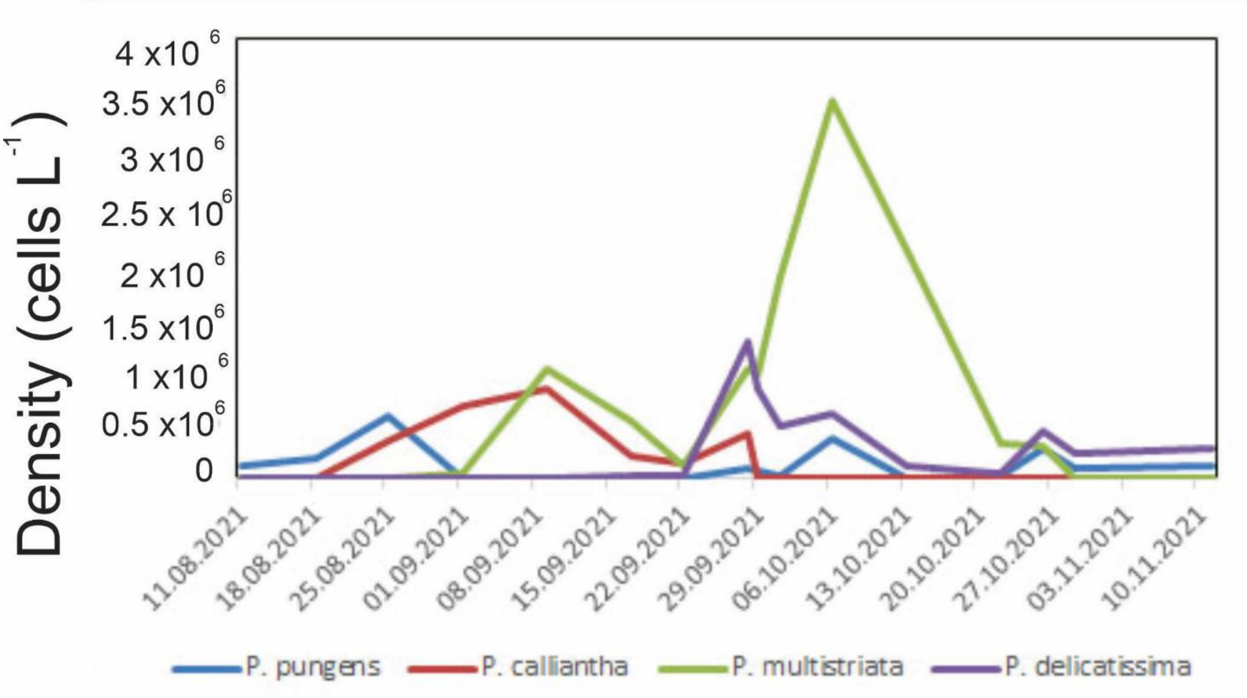

Fig. 1. Cell density of *Pseudo-nitzschia* spp. in the surface horizon at the monitoring station in Amur Bay in the summer and autumn of 2021.

An accumulation of domoic acid was detected in the samples of the bivalves *Modiolus kurilensis* (2 mg kg^{-1}) and *Crenomytilus grayanus* (0.9 mg kg^{-1}) collected in late October 2021 after bloom events caused by *P. multistriata* and *P. delicatissima*. These concentrations of domoic acid were substantially below the regulatory limit of 20 mg kg^{-1}, and, nevertheless, significantly higher than the concentrations (0.1–0.3 mg kg^{-1}) previously reported for bivalve samples from this area (Stonik et al., 2019). No cases of ASP were recorded.

In 2022, the summer bloom of phytoplankton in the Amur Bay has become the longest in time (for approximately one and a half months) for the entire 30-year period of microalgae monitoring in Peter the Great Bay. The concentration of the species that caused it has also reached the maximum values for this region. No cases of human poisoning or animal mortality were recorded.

As the results of the monitoring of hydrological characteristics show (Fig. 2), from July 13 to August 9, 2022, the sea surface temperature (SST) increased from 21 to 27.1°C; sea surface salinity (SSS) varied from 0 to 10 ppm; chlorophyll *a* concentration varied from 10 to 64 mg m^{-3}. Along the transect, the average thickness of the layer with chlorophyll *a* concentrations (higher than 2 mg/m^3) increased from 3 to 6 m. The turbidity (concentration of suspended particles in the water) was greater than 60 mg/m^3. Oxygen in the surface layer of water, due to the long-term and intense microalgae bloom, reached 170%, which corresponds to a significant oxygen saturation of water, while low oxygen concentrations (less than 4 mg L^{-1}) indicating hypoxia were recorded from the near-bottom layer of water (up to 5 m thick).

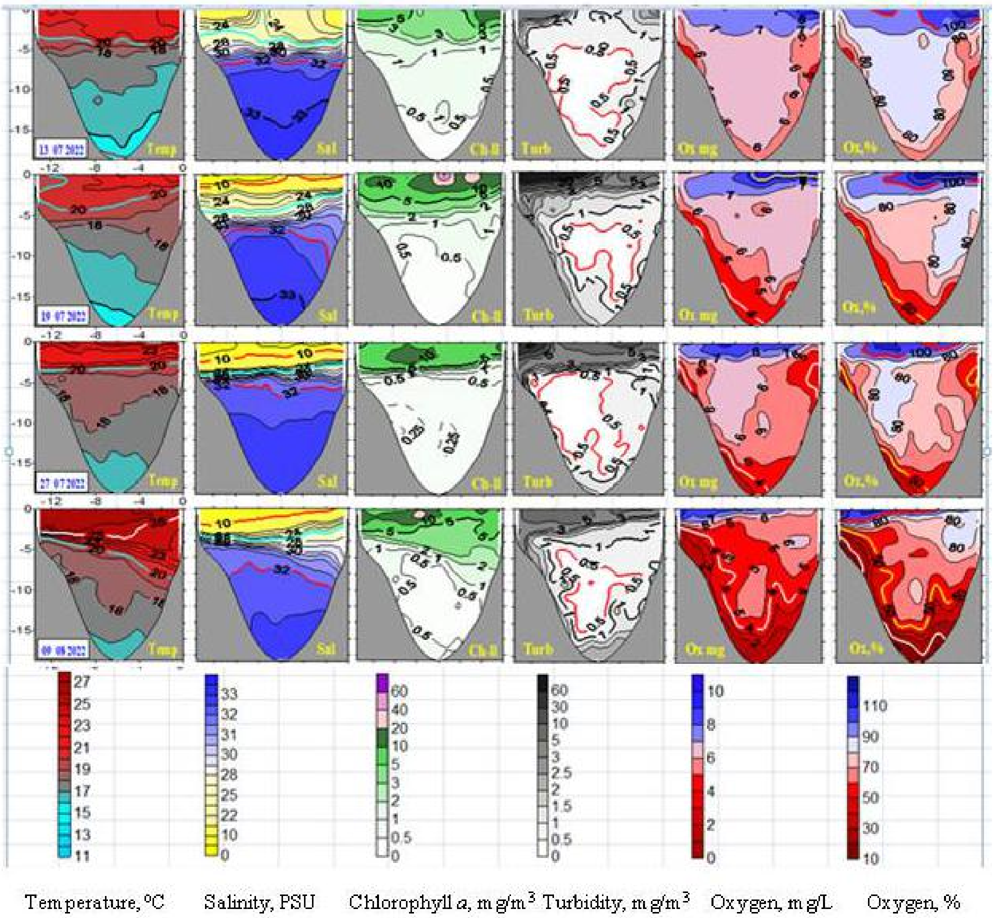

Fig. 2. The results of the monitoring of hydrological characteristics in Amur Bay along the transect line from Cape Krasny to Peschanaya Cove from July 13 to August 9, 2022.

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Overview – West Coast incidences of HAE produced mostly Domoic acid, and PSTs, though there were often infrequent reports of DSTs, shellfish killing toxins (yessotoxin), and there was some evidence of freshwater cyanotoxins transferred to marine habitats (including Alaska). There were continued incidences of marine mammal strandings in 2021-2022, with a current HAB event in California that is causing many marine mammal strandings. There were periodic commercial fishery closures in all four states (California, Oregon, Washington, and Alaska). In California, Oregon, and the Washington outer coast, closures were due to domoic acid routinely (CA and WA outer coast) and PSTs (WA and AK). Continued efforts for more offshore HAB sampling, modeling/forecasting of domoic acid, ocean acidification and multi-stressor events, satellite/remote sensing for HABs, identification of new/emerging HABs, and freshwater toxin transfer to the marine environment are areas of interest for academic, governmental, and tribal harmful algae researchers. Use of IFCB technology is a key technology and the US west coast network is expanding. Several NOAA ECOHAB and MERHAB projects were funded in 2021 to address HABs on the west coast.

California – Is monitored by HABMAP, Coastal Ocean Observing System, and multiple state, federal, academic, private, and tribal partners for harmful algae and toxins. Sampling is still decreased due to COVID-19 lab closures compared to pre-2020. There were punctuated *Pseudo-nitzchia* reporting in Southern-Central California, typically in spring, though it continued into fall 2021.There were marine mammal strandings during the spring in California (few) and currently (August-Sept 2022) CA is in the midst of a large (likely) offshore DA event, which is causing many mammal strandings. *Alexandrium* incidences were infrequent or non-existent in southern California, but were present above 10,000 cells/L in central and northern California, and Northern California was closed due to PST toxins in shellfish in the summer/fall of 2021 and summer of 2022. Razor clam fisheries were closed in northern California from December 2021 – June 2022 because of domoic acid. August – Sept 2022, central and northern CA are closed due to PSTs, and also an unprecedented *Heterosigma* HAB event in San Francisco Bay which is linked to fish kills. Closures due to *Dinophysis* and DSP events were not reported, and *Dinophysis* was infrequent in samples. There were multiple ASP and PSP commercial and recreational harvest closures throughout California, though they were short-lived. California continues to produce a state-wide HAB newsletter (CA HAB Bulletin), weekly updates by email, and use of the C-HARM model for Domoic acid forecasting. Central and Southern California have also began including freshwater toxins found in the marine environment in weekly/monthly updates to the harmful algae community. There is a statewide Imaging FlowCytobot System for harmful algae which can be accessed at https://ifcb.caloos.org/dashboard.

Oregon - Is monitored for HA by the ORHAB and SoundToxins monitoring programs, as well as the state of Oregon public health (shellfish). In 2021 from north to south, there are higher cell counts for *Pseudo-nitzschia* (both large and small) and greater concentrations of pDA, with toxic events happening in April - June, and September- November. Throughout 2021, both *Alexandrium* and *Dinophysis spp*. were present periodically at sampled sites. There were commercial and recreational shellfish biotoxin closures for PSP events in November 2021, February and May 2022. There were no reported marine mammal strandings due to biotoxins

Washington – Is monitored for harmful algae by the ORHAB, SoundToxins, Washington Dept. of Health programs, and tribal nations. There were PSP events in multiple counties of Washington, along the entire coast of Washington State, including the inland Salish Sea. The State analyzed ~2500 shellfish samples for PSP, DSP, and/or ASP. There were multiple commercial and recreational closures, though fewer than in 2020. ASP events are confined to the coast (southern Washington) though *Pseudo-nitzschia* was seen throughout Washington state sampling locations, and into the South Salish Sea (Puget Sound). DSP events were mostly confined to inner Puget Sound though there were no commercial DSP closures. In Northwest Washington there were more than 30 subsistence harvest closures for PSP and/or DSP events in 2021, which is less than in 2020. There are still periodic tribal beaches closed currently in the Northern Washington, mainly to PSP. There was one confirmed hospitalized illness for PSP in Washington state last year. There were fewer shellfish die-offs compared to 2021. Monitoring efforts to identify other yessotoxin shellfish die-off events are currently ongoing, as is the implementation of an IFCB network. There is also current work being done to monitor for DA offshore of Washington coast. DSP and PSP events did not continue into the winter (January and February) in 2021, but there are current blooms of both *Protoceratium reticulatum* and *Alexandrium* spp. in the North Salish Sea that is impacting shellfish harvests. Several NOAA ECOHAB and MERHAB projects to monitor for HABs (using IFCBs, AUVs, ESPs, and more traditional methods) were funded for Washington state, as was support to expand data collection through citizen science, tribal, academic, and state partners.

Alaska – Alaska is being monitored by Alaska Harmful Algal Bloom network (AHAB), SoundToxins, Southeast Alaska Tribal Ocean Research (SEATOR), Kachemak Bay National Estuarine Research Reserve (KBNERR), Alaska Sea Grant, Aleutian Pribolof Island Association, NOAA, and other tribal, governmental, and academic groups. There continues to be elevated levels of PSTs found in shellfish throughout the year at various SE Alaska beaches. In SE Alaska, ~ 1000 shellfish and ~500 water samples were monitored for *Alexandrium*, and PSTs, including cysts. Near commercial and subsistence geoduck beds an alarming number of *Alexandrium* cysts were present, but there has (of yet) been no correlation between cyst presence and winter geoduck toxicity. Samples from SE Alaska routinely saw PSTs in salmon kidneys and livers, but not edible meat and eggs. Kodiak, Alaska sampled in 2021 was >80% of the time above the regulatory limit for PSTs at one beach, but less than 10% at the other two beaches, showing the difficulties in providing shellfish safety measures for subsistence harvesters. The Aleutian and Pribilof Islands sampled weekly in 2021, and similar to Kodiak sampling, blue mussel samples were sometimes above the regulatory limit for PSTs, though not with the toxicity levels of 2020. The Bering Sea had clams with elevated PSP levels, and both ASP and PSP were found in stranded or harvested marine mammals' stomachs. There is a new publication (Anderson et al. 2022) in *Oceanography* describing some of the HAB incidences in the Alaska arctic from the last few years. Similar to other US west coast states, Alaska has newly funded ECOHAB (NOAA) projects aimed at monitoring for PSTs and domoic acid by mapping cell densities and health assessments from marine mammals. Alaska has the most extensive network of citizen scientists monitoring for (mainly) PSTs, where 100% of coastal Alaskans subsistence harvest. The AHAB network and website presence has been updated substantially in the last year, and facilitates gathering HAB data into one location.