PACIFIC SALMON FOUNDATION

PHYTOPLANKTON AND HARMFUL ALGAE

Citizen Science Program

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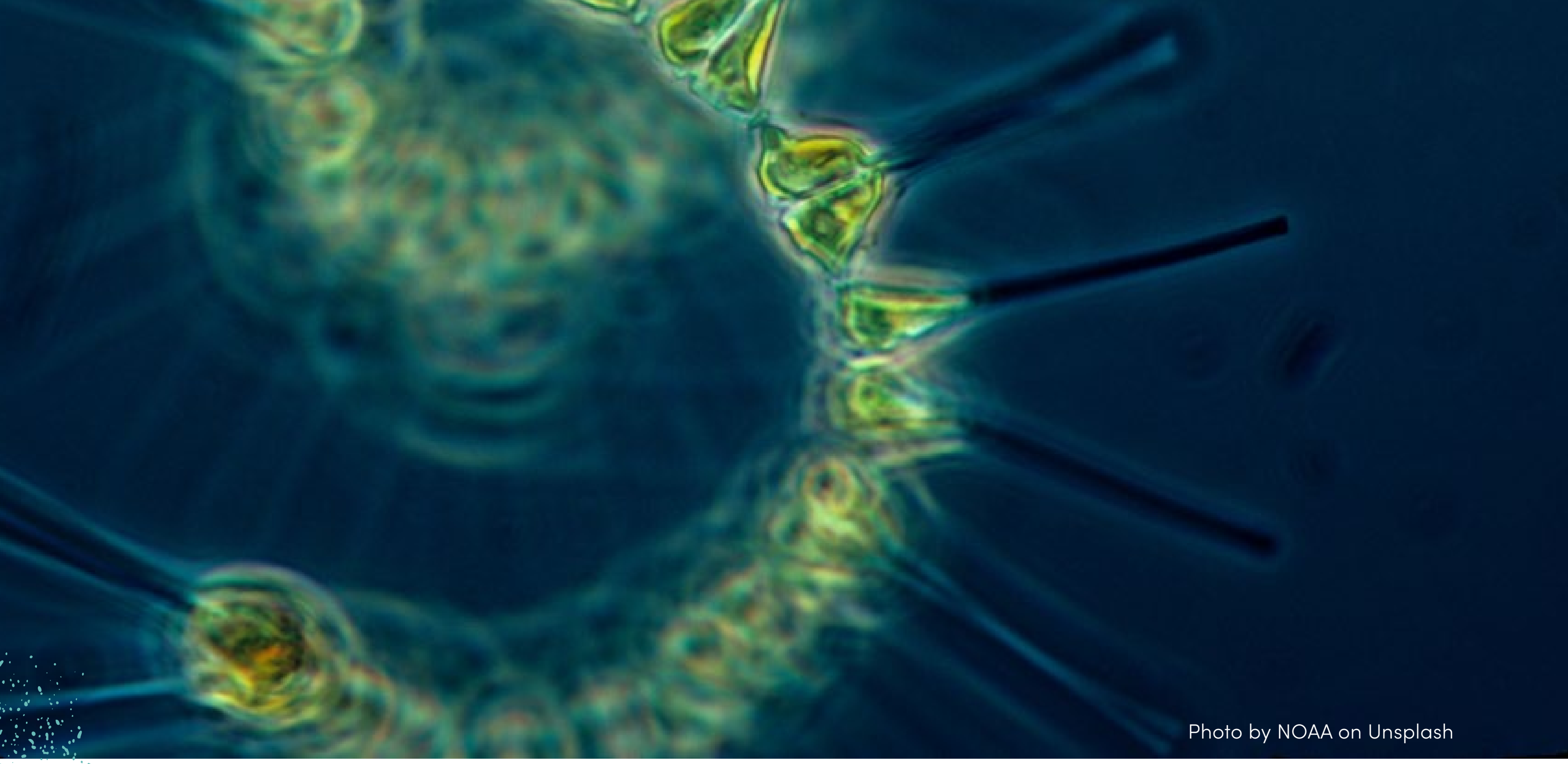


Photo by NOAA on Unsplash

WHAT IS PHYTOPLANKTON AND IS IT IMPORTANT?

Phytoplankton are microscopic organisms that float in the upper layer of the ocean. They utilize photosynthesis to convert sunlight and nutrients into organic matter, serving as the foundation of the oceanic food web. Most marine life depends on phytoplankton as a primary food source, either directly or indirectly. Zooplankton, which are small animals, feed on phytoplankton and are subsequently preyed upon by larger organisms, such as fish and marine mammals. The abundance of phytoplankton in the ocean is crucial for maintaining the health of the marine ecosystem, as it provides the necessary energy for sustaining all other forms of life. Changes in the phytoplankton population can have significant impacts on the rest of the food web.

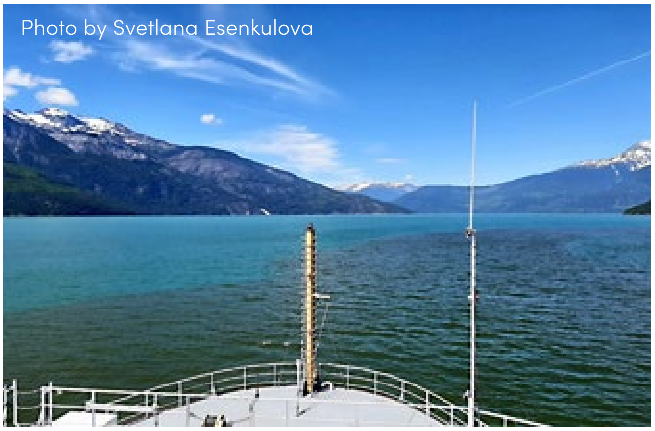
WHAT ARE HARMFUL ALGAL BLOOMS?

Although phytoplankton is essential in supporting oceanic life, certain species can pose a threat to humans, animals, and the environment. Some produce toxins that can accumulate in shellfish, leading to paralytic, amnesic, and diarrhetic shellfish poisoning (PSP, ASP, and DSP). Others can release toxins that are deadly to fish and marine mammals. Some species have long spikes that can irritate fish gills and even cause suffocation and death. Additionally, dense blooms of any phytoplankton species can deplete oxygen levels due to bacterial activity during decomposition, endangering aquatic life that requires sufficient dissolved oxygen to survive. While harmful algal blooms (HABs) have always been part of the marine ecosystem, their frequency, intensity, and distribution have increased in recent decades. Climate change may further exacerbate the proliferation of HABs.

Photo by Svetlana Esenkulova

Pseudo-nitzschi bloom

Cover photos by Mitch Miller (top and centre) Michael Bahrey (left), and Svetlana Esenkulova (right)



Heterocapsa triquetra bloom

DO WE HAVE HARMFUL ALGAL BLOOMS IN BRITISH COLUMBIA?

Yes. And in fact, the very first scientific account of a HAB in the world was reported from BC! In 1793, during Captain George Vancouver's explorations of the Pacific Northwest, he encountered a harmful algal bloom off the coast of British Columbia, Canada. The bloom caused local shellfish to become toxic, leading to illness among members of Vancouver's crew who consumed the contaminated shellfish.

Currently, HABs in BC regularly cause severe economic losses through finfish/shellfish mortalities and shellfish harvest closures due to toxin accumulation. Unfortunately, HABs are not considered an ecosystem stressor by DFO, and therefore, there is no systematic monitoring and research on a government level.

The PSF recognized the critical lack of knowledge in this area and incorporated phytoplankton taxonomy studies into some of their programs. This started during the Salish Sea Marine Survival Project (SSMSP) in 2015, where purse seine collections of juvenile salmon, combined with histological examination of the fish together with water sampling revealed that wild juvenile salmon may be affected by HABs in nearshore environments in a similar way as farmed salmon (Esenkulova et al., 2022).

Currently, HABs monitoring is an integral part of the PSF Citizen Science Oceanography Program and over a thousand phytoplankton samples are collected and analyzed every year. Based on this unprecedented monitoring, we have learned that harmful algae are very common and abundant in the Strait of Georgia. Moreover, they often reach concentrations causing negative impacts on aquacultured shellfish and fish. However, due to a lack of ecosystem based studies, it remains unclear how exactly these blooms affect wildlife and the marine environment as a whole.

CLIMATE CHANGE AND HARMFUL ALGAL BLOOMS

There is a consensus among scientists that climate change is expected to worsen HABs in the coming years. As the planet warms, water temperatures are also rising. This can lead to an increase in "windows of opportunity" for many algal species. Additionally, changes in ocean currents, and precipitation patterns, including increased rainfall and flooding events, can lead to higher stratification and nutrient runoff into the ocean, creating favorable conditions for HABs.

Long-term, consistent phytoplankton monitoring is especially important now, as climate change is expected to accelerate. By monitoring algae, scientists can better understand their triggers and work towards mitigating HABs in the future. Additionally, consistent monitoring can help us anticipate and prepare for future changes, allowing us to better adapt to the impacts of climate change.

WHY DO WE NEED HABS MONITORING?

Monitoring tells us where and when HABs occur, and reveals patterns and trends. Further analysis can establish links with environmental parameters, which, in turn, may allow for the development of predictive models. Long-term data make it possible to assess and evaluate the effects of HABs on various aspects of the marine ecosystem, including wild salmon stocks. The impacts of HABs must be studied to reduce uncertainty and ensure an ecosystem approach to local fisheries management. Understanding the ecological impacts of HABs can help us better manage fisheries, aquaculture and ensure that we are protecting the health and well-being of both marine life and humans who rely on these resources.

MEET SOME OF THE HARMFUL ALGAE PSF MONITORS IN THE STRAIT OF GEORGIA

After eight seasons of the PSF Citizen Science Oceanography program we have learned a lot. The following are some of the harmful algae that are often found in the Strait of Georgia along with lessons we have learned based on samples we have collected.

ALEXANDRIUM

What is it: Alexandrium (Figure 1) is a dinoflagellate genus with most species producing a toxin known as 'saxitoxin'. This potent toxin is harmful to both marine animals and humans by blocking the transmission of nerve impulses from motor neurons to muscles. When Alexandrium is present in water, even at low concentrations, saxitoxin accumulates in shellfish. Consuming such shellfish can lead to paralytic shellfish poisoning (PSP). Symptoms of PSP include tingling, numbness, dizziness, and difficulty breathing, and it can be fatal in severe cases. To prevent human illness, shellfish harvesting closures are put in place when saxitoxin above safe limits is detected in shellfish.

Lessons we have learned: Alexandrium is very common in the Strait of Georgia. It thrives in the summer months and prefers warm and stratified waters. Based on eight years of data, it appears that Alexandrium abundance is tightly linked to large-scale climatic phenomena – the El Niño Southern Oscillation (ENSO). It was approximately 25% less common during El Niño years compared to La Niña years, which is somewhat unexpected since El Niño is a warm phase of ENSO and Alexandrium grows better in warmer waters. The final highlight of the findings is that the Canadian Food Inspection Agency (CFIA) detects higher levels of PSP concentrations in shellfish flesh during years when Alexandrium is more abundant.

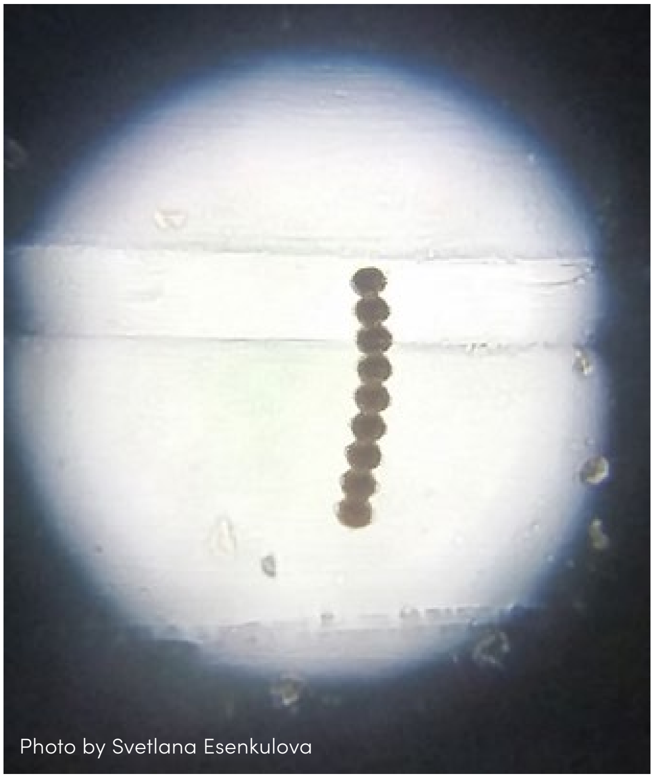


Figure 1: *Alexandrium cells under a microscope.*

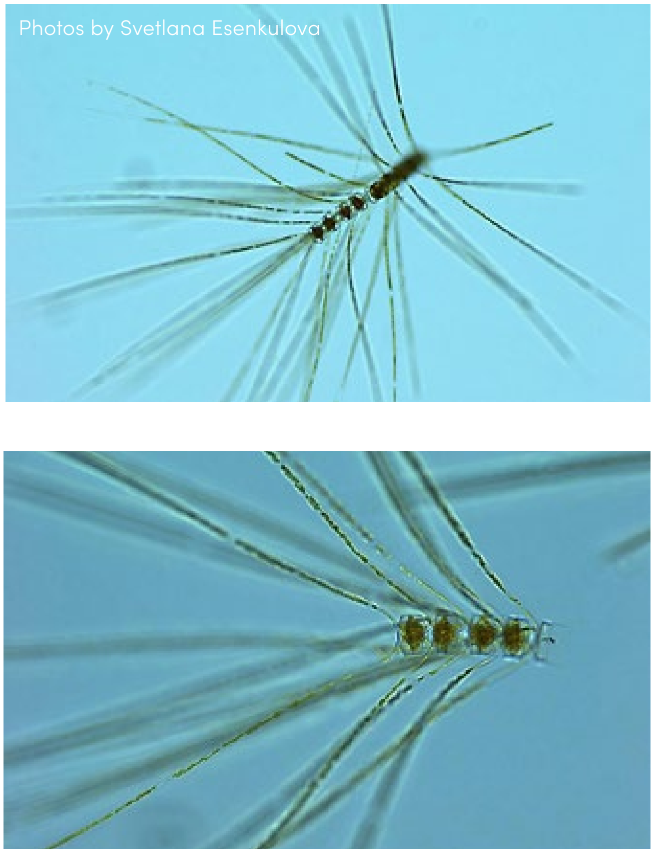


Figure 2: *Chaetoceros cells under a microscope.*

CHAETOCEROS CONVOLUTUS AND *C. CONCAVICORNIS*

What is it: *Chaetoceros convolutus* and *C. concavicornis* are diatoms with very long 'spikes' (Figure 2). These algae can get stuck in gills and with prolonged exposure can cause mechanical damage, and even fish kills on salmon farms due to suffocation.

Lessons we have learned: Opposite to other harmful algae, these two are the most common during spring and fall, in cold, nutrient-rich, deeper waters. During the Salish Sea Marine Survival Project (SSMSP) juvenile salmon studies, it was found that the gills of wild juvenile salmon had damage, which may have been associated with exposure to *Chaetoceros convolutus* and *C. concavicornis*. The salmon's gills had lesions, excess mucus, and areas of epithelial hyperplasia and necrosis (Figure 3). The observed gross pathology was consistent with the symptoms observed in BC farmed salmon affected by these species. It implies that wild salmon may be affected by HABs in the same way as fish in net pens.

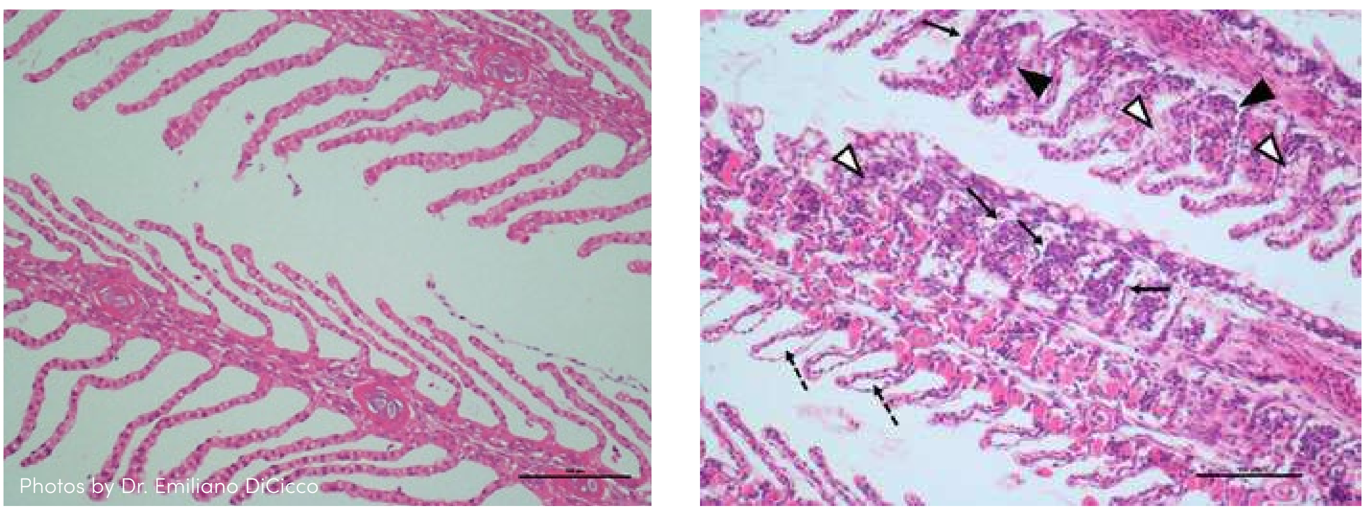


Figure 3: *Histology samples showing healthy gill tissue (left) and damaged gill tissue of a chum salmon collected June 29, 2015 in Cowichan Bay after* Chaetoceros convolutus *event (right). The arrows point to different lesions and signs of damage including epithelial hyperplasia (arrows) and necrosis (arrowheads), excess of mucus (hollow arrowheads), and gill's oedema and detachment of epithelial cells (dashed arrows). Scale bars are 100µm. From Esenkulova et al., 2022.*

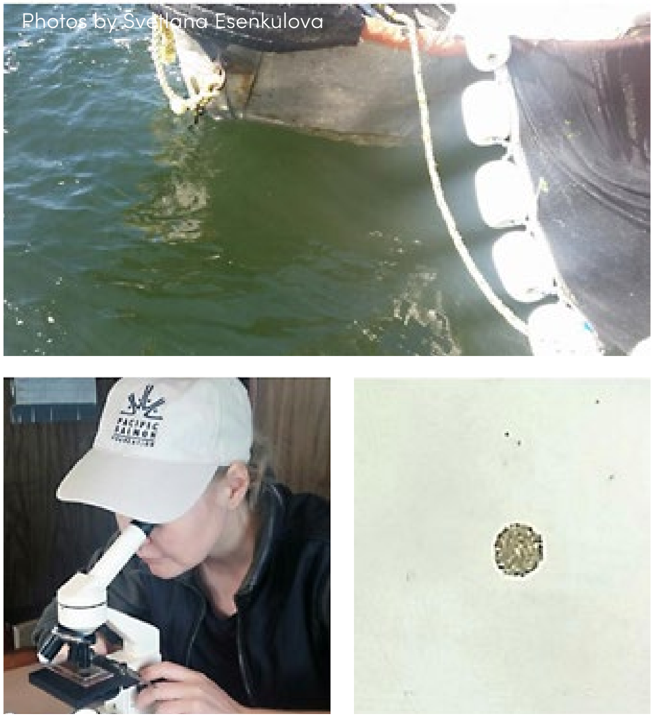


Figure 4: Top shows Dictyocha bloom. Bottom left shows identification by PSF biologist Svetlana Esenkulova using a microscope and bottom right shows a Dictyocha cell under a microscope.

DICTYOCHA SPP.

What is it: Dictyocha is a genus belonging to silicoflagellates (Figure 4). It often has a 'skeleton' made out of silica. Some species are considered toxic to salmon.

Lessons we have learned: Dictyocha is quite abundant throughout the entire sampling season. It forms dense blooms close to river inputs (for example, Fraser and Cowichan Rivers). It thrives in waters that are silicate-rich, low to moderate salinity, and highly stratified. During SSMSP juvenile salmon studies, it was found that during a Dictyocha bloom, wild salmon livers had signs of reduced glycogen stores (a sign of starvation), swelling of hepatocytes (a sign of injury to liver cells) and nuclear apoptosis (a break down and death of cells) (Figure 5). Observations of distinct histological changes during HABs suggest these phytoplankton may be directly affecting wild juvenile salmon survival.

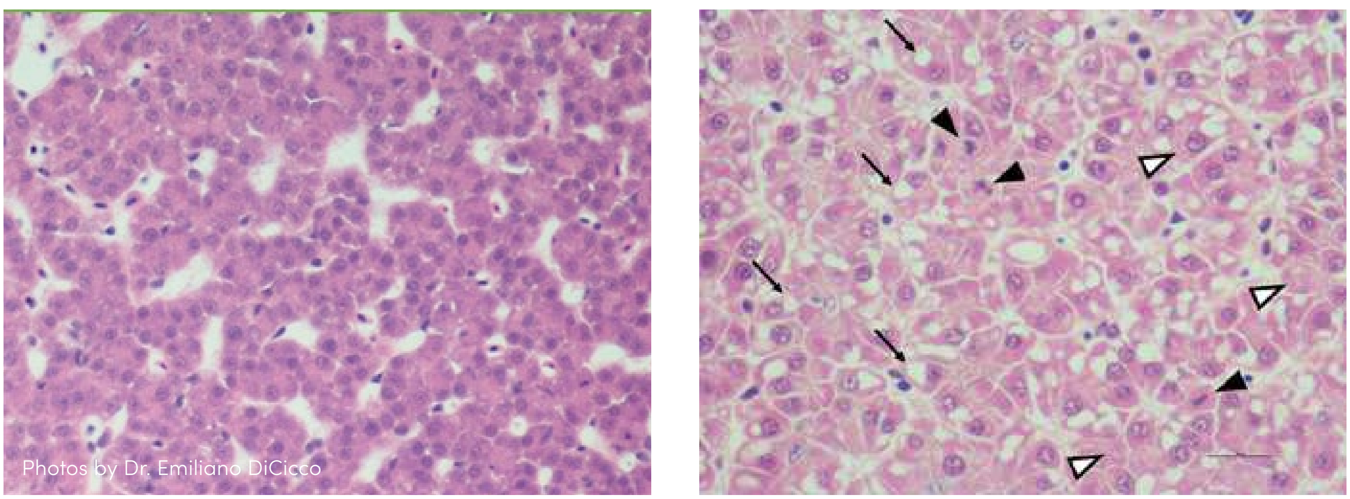


Figure 5: Histology samples showing liver tissue (left) and damaged liver tissue of a Chinook salmon collected June 29, 2016 in Cowichan Bay during a Dictyocha bloom (right). The arrows point to different lesions and signs of damage including the widespread presence of vacuoles in hepatocytes, an indication of hydropic degeneration (arrows), along with some apoptotic nuclei of hepatocytes (arrowheads). Some accumulation of glycogen is still observable (hollow arrowheads). Scale bar - 20µm. From Esenkulova et al., 2022.

HETEROSIGMA AKASHIWO

What is it: Heterosigma is a toxic raphidophyte that causes fish kills around the world (Figure 6). In BC, it is one of the primary causes of farmed salmon losses, with direct annual losses estimated at millions of dollars (Haigh and Esenkulova, 2014). Heterosigma blooms were also statistically linked to poor wild Sockeye salmon survival (Rensel et al., 2010) and drastically increased post-PIT-tagging wild juvenile salmon mortality during SSMSP (Esenkulova et al., 2022).

Lessons we have learned: The timing of the Fraser River freshet and resulting stratification are key factors for Heterosigma bloom development in the Strait. Seasonally, Heterosigma is negatively linked to phosphates, rainfall, and cloud cover. In the last eight years, 2015 had particularly low Heterosigma, while 2018 had particularly high levels. Long-term sampling studies, including assessment of additional variables, would be crucial to further our understanding of the key drivers of this species.

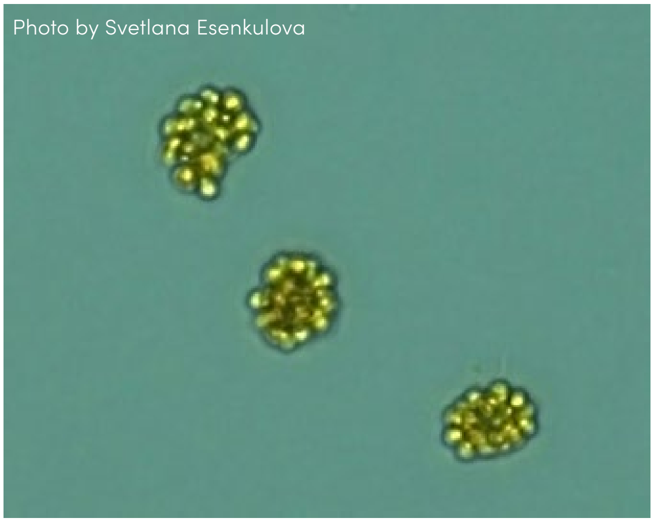


Figure 6: Heterosigma akashiwo cells under a microscope.

NOCTILUCA SCINTILLANS

What is it: Noctiluca is a dinoflagellate that forms dense, vivid orange blooms and is also known for its bioluminescent properties (Figures 7 and 8). It is heterotrophic, meaning rather than creating its own food through photosynthesis, it eats other algae, bacteria, and even small zooplankton. Due to this, their blooms can cause disruption of marine food webs. Additionally, Noctiluca produces ammonia as a by-product of its metabolism. High levels of ammonia can have negative impacts on water quality and marine life. Opposite to common belief, it does not cause PSP.

Lessons we have learned: Noctiluca has heavy blooms in some years, and when it blooms, it is usually close to the shore. These blooms are quite spectacular from all angles — from the boat or shore, plane or satellite, and tend to attract the most public interest. However, among all the species described here, they are the least directly harmful to salmon.

Figure 7: Noctiluca scintillans cell under a microscope.

Figure 8: Striking Noctiluca scintillans blooms as seen from a seaplane (above) and on the water (left). Although Noctiluca blooms appear quite shocking, among all the species described here, they are the least directly harmful to salmon.

WHERE DO WE GO FROM HERE?

Thanks to the PSF Citizen Science Program's unprecedented monitoring efforts, we now know that harmful algae and their blooms are widespread in the coastal waters of British Columbia. While we have identified their presence and environmental preferences, the full extent of their impact on the ecosystem remains unclear. However, by combining the collected dataset with information on higher trophic level data (e.g., zooplankton and fish), we can analyze the interactions between physical oceanographic parameters, food web dynamics, and potential outcomes for fish stocks.

Through the study of the dynamics and impacts of algae on juvenile salmon, researchers can better understand the relationships between oceanographic conditions in the Strait of Georgia and the survival and growth of juvenile fish, which are of cultural and economic significance in the region. Long-term monitoring data can inform management strategies, such as developing early warning systems and forecasting models, and implementing targeted response plans.

The PSF Citizen Science Program has shared information with various governance structures, including the Canadian Food Inspection Agency, BC Centre for Disease Control, and First Nations Health Authority. This information can be used to enhance public education and outreach efforts, such as promoting food safety practices for shellfish consumers and ensuring public health.

CAN I CONTRIBUTE TO HABS STUDIES?

Yes! The PSF Citizen Science Oceanography Program relies on coastal residents who care about the ocean and are passionate about its health. We believe that residents are the best stewards of the ocean, and we would like to encourage you to share your knowledge with us! If you see anything unusual in your waters, please gather field notes (including time and location), take photos, and collect a water sample, if possible.

To collect a water sample, use a plastic or glass container and store it in a cool place out of direct sunlight. Stored like this, the sample can maintain identifiable algae for a couple of days. To preserve it longer — up to a couple of months, you can add a few drops of Lugol's Iodine to the sample, until it takes on a tea-coloured hue (Figure 9). Lugol's Iodine can be obtained from any pharmacy as it is commonly used as an antiseptic for minor scratches. Follow up with Svetlana Esenkulova at sesenkulova@psf.ca to share your sample and notes.

Please let us know if you witness any unusual events, and we will be happy to assist you in analyzing the sample. Together, we can continue to monitor the health of our coastal waters and work towards maintaining a healthy ecosystem.

Figure 9: *Adding Lugol's Iodine to water samples with phytoplankton will preserve them for months. You want to add drops of iodine until the sample is a tea-like colour.*

WHERE TO LEARN MORE ABOUT PSF CITIZEN SCIENCE MONITORING AND HABS?

- A detailed description of the PSF Citizen Science program, methods and data analysis of the first several years of HABs monitoring are summarized in the peer reviewed paper "Harmful Algae and Oceanographic Conditions in the Strait of Georgia, Canada Based on Citizen Science Monitoring" by Esenkulova et al., 2021
- Annually updated graphs and figures can be found in the Atlas of Oceanographic Conditions in the Strait of Georgia
- A summary of HABs dynamics and oceanography is included in the annual DFO report — State of the Pacific Ocean
- Raw data are located on the Strait of Georgia Data Center
- Real-time updates on notable HABs events are shared via social media (facebook.com/CitizenSciencePhytoplankton)

References

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