Linkages among harmful algae, marine biotoxins in shellfish, and oceanographic conditions in the Strait of Georgia, Canada

Svetlana Esenkulova, Nicole Frederickson, and Isobel Pearsall

Pacific Salmon Foundation, Vancouver, BC

September, 2022

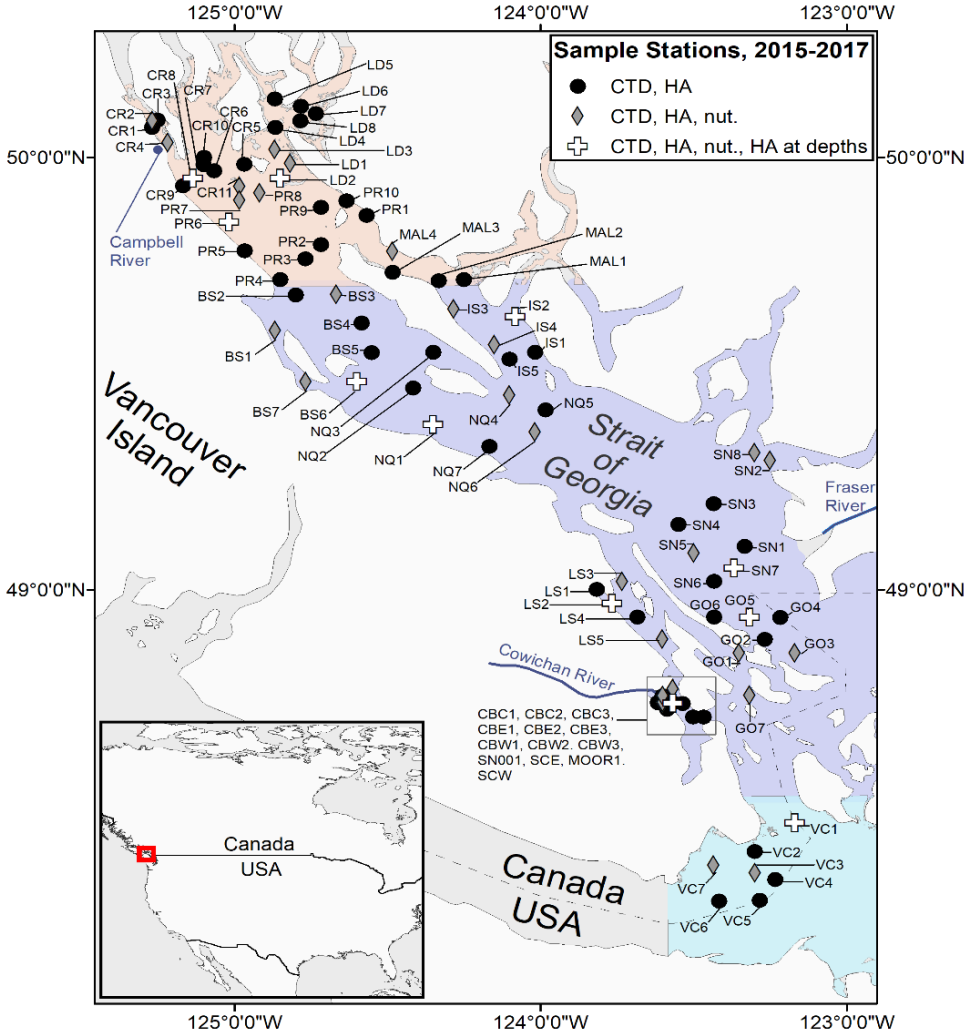
Harmful algae history and research in Canada

- Coastal waters of British Columbia (BC), Canada have one of the longest documented histories of Paralytic Shellfish Poisoning (PSP) in the world (Vancouver, 1798)
- A monitoring program for the presence of toxins in shellfish was established in the 1940s (Taylor and Harrison, 2002). Since then, numerous PSP closures have been occurring every year
- The first DSP in BC was confirmed only recently (Taylor et al. 2013)
- Shellfish sector value in BC ~ $20 million
- Canadian Food Inspection Agency (CFIA) – monitor toxins in shellfish flesh; Department of Fisheries and Oceans Canada (DFO) – enforce closures.
- No government-led harmful algae monitoring, limited research
- Pacific Salmon Foundation (PSF) is a federally incorporated non-profit charitable organization
  - Goal: conservation and restoration of wild Pacific salmon

PSF Citizen Science Program (CitSci) 2015- ongoing

"scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions"

Pacific Salmon Foundation + Ocean Networks Canada + Department of Fisheries and Oceans



Strait of Georgia ~7000 km^2
~50 stations

20 trip/year
February – October: 2/3 times a months
November – January: once a month

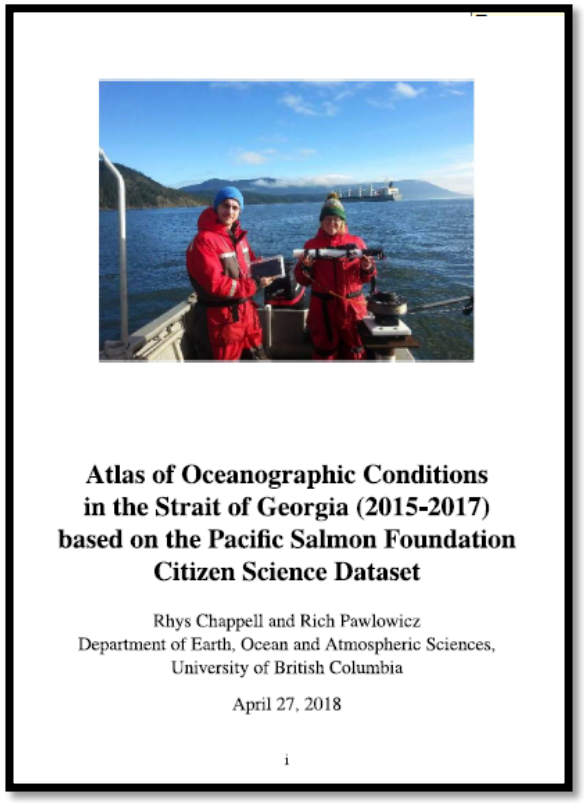
CTD, Phytoplankton, Secchi – each station
Nutrients ~30 stations

https://www.marinescience.ca/citizen-science-programs/

Data

Raw data
http://www.oceannetworks.ca
http://sogdatacentre.ca/

pearsalli@psf.ca – Dr. Isobel Pearsall



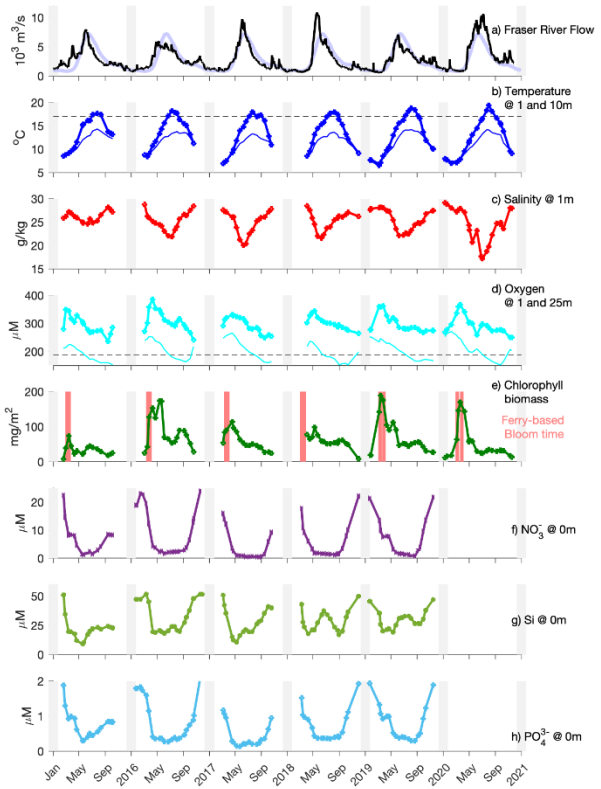
Summary data
R. Pawlowicz, et al, 2020, **Atlas of oceanographic conditions in the Strait of Georgia (2015-2019) based on the Pacific Salmon Foundation's citizen science dataset**, Canadian Technical Report of Fisheries and Aquatic Sciences 3374

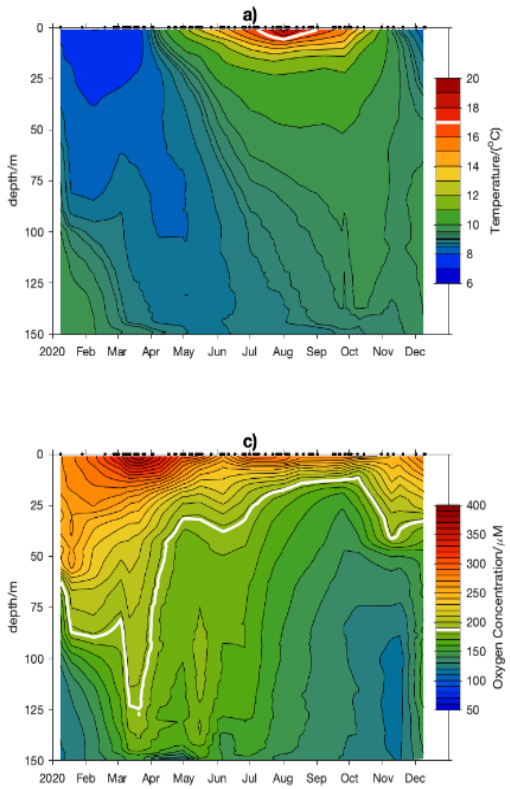
Digital atlas - updated annually
R. Pawlowicz and B. Boufford, **Atlas of oceanographic conditions in the Strait of Georgia**, **https://sogdatacentre.ca/atlas/**

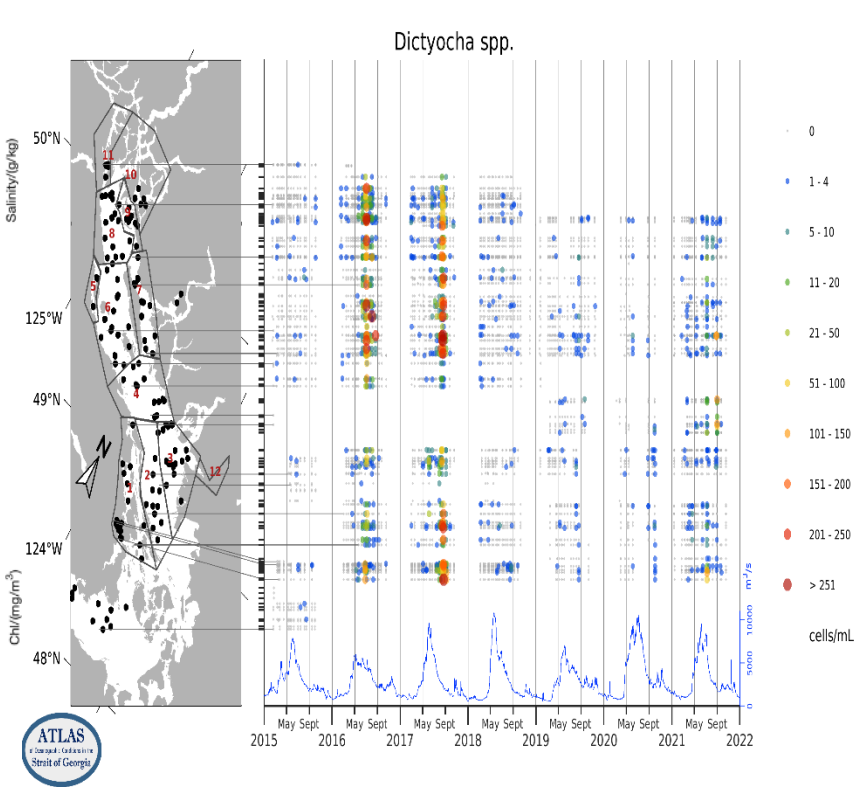
State of the Pacific Ocean -Can.Tech.Rep.Fish.Aquat.Sci.

Esenkulova, S., Pawlowicz, R., Frederickson, N., Ross, A., Pearsall, I. 2022 contributed 'SPRING-SUMMER OCEANOGRAPHIC CONDITIONS AND HARMFUL ALGAL BLOOMS IN THE STRAIT OF GEORGIA 2021

https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41067113.pdf

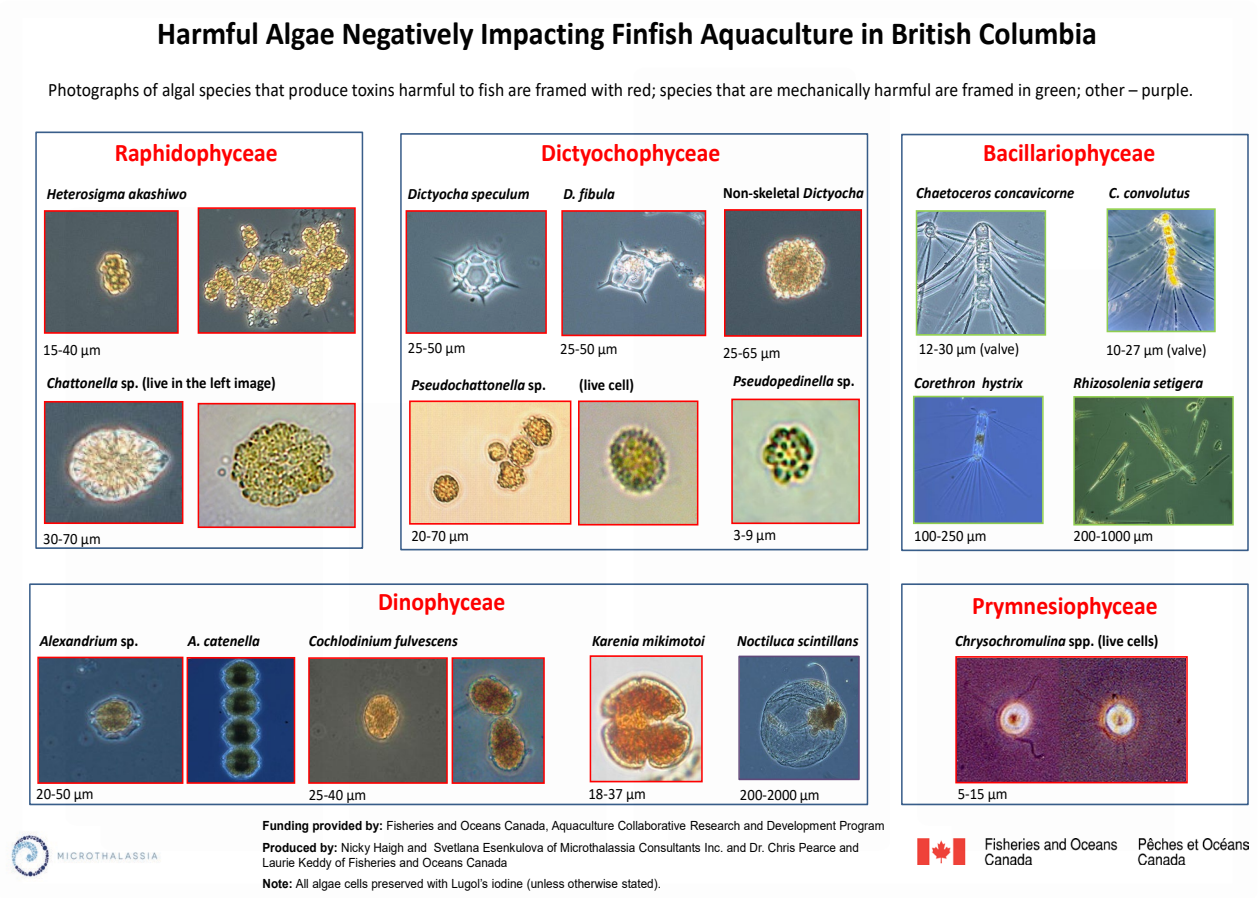






Peer-reviewed papers

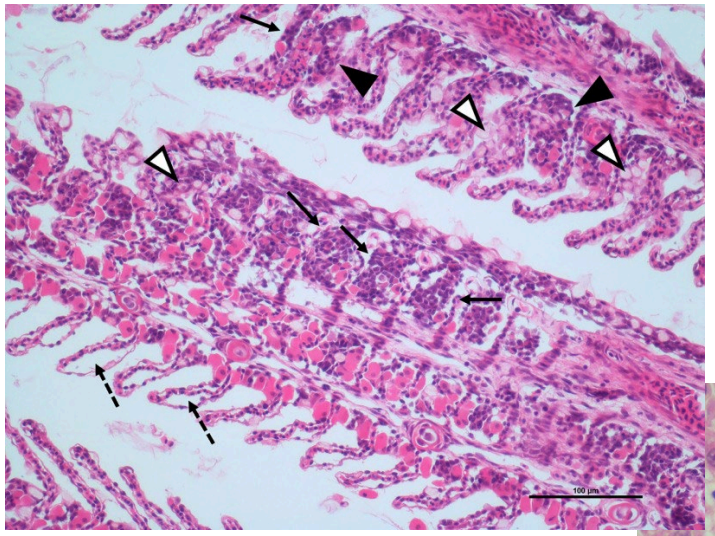
S. Esenkulova, K. Suchy, R. Pawlowicz, M. Costa, and I. Pearsall, **Harmful Algae and Oceanographic Conditions in the Strait of Georgia, Canada, Based on Citizen Science Monitoring,** Frontiers in Marine Science, 09 September 2021



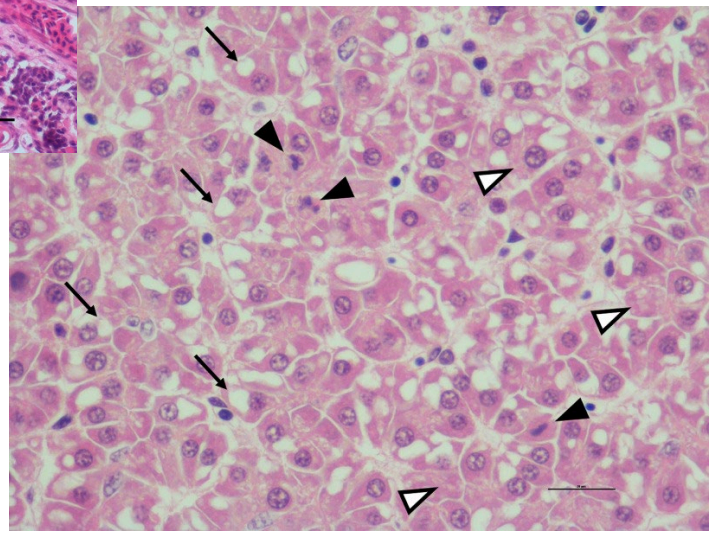
- Harmful algae are **very common** in the Strait of Georgia
- They are present in 9% (April) to 51% (August) of samples from February to October (n=5000)
- They often reach concentrations associated with negative impacts in aquaculture (shellfish and salmon)

Peer-reviewed papers

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.



Gill lesions post
Chaetoceros convolutus



Liver degeneration signs
during *Octactis speculum*

- Chinook salmon reduced their feeding during dense blooms
- Salmon gills were damaged after *Chaetoceros convolutus* 'bloom'
- Salmon livers had distinct pathology during *Octactis speculum* 'bloom'

Algae important to shellfish safety, Strait of Georgia

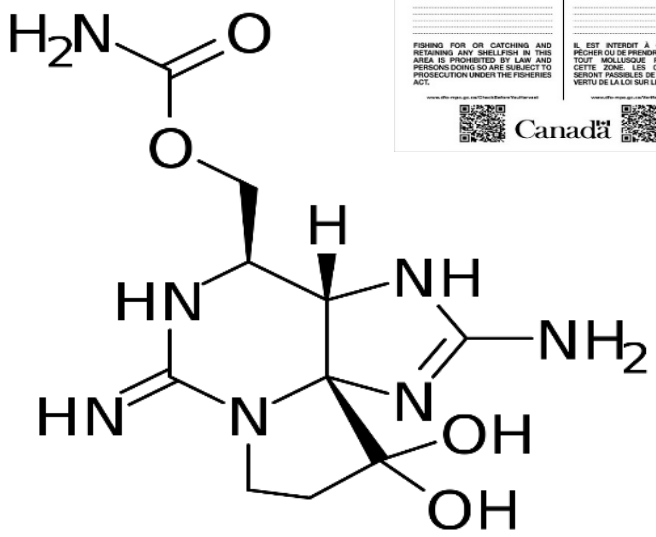
- PSP closures – very often. ***Alexandrium*** spp.
- DSP closures – rarely. ***Dinophysis*** spp.
- ASP closures – almost never. ***Pseudo-nitzschia*** spp. (non toxic in the Strait)

Alexandrium is one of the most common monitored HA taxa in SoG and occur in ~15% of the samples; *Dinophysis* occur in < 2.5% (Esenkulova et al., 2021)

Month	Feb	Mar	Apr	**May**	**Jun**	**Jul**	**Aug**	Sep	Oct
Alexandrium spp.	0.0	5.5	8.7	17.8	21.1	22.0	**25.0**	15.9	0.0
Dinophysis spp.	0.0	0.8	0.8	3.5	**4.3**	3.4	3.0	0.4	0.9

Harmful algae - shellfish

Year	Alexandrium %	PSP-total (ug STXdiHCl eq/100g)	Dinophysis %	TOX-DSP-LC (ug/g)
2015	**10.7**	**180**	1.7	0.12
2016	16.3	960	**0.7**	**0.008**
2017	**18.1**	**2100**	1.6	0.13
2018	15.7	900	**5.1**	**0.25**



Saxitoxin is produced by some *Alexandrium* species, cause Paralytic Shellfish Poisoning

Higher toxin concentrations of PSP (PSP-total) and DSP (TOX-DSP-LC) in shellfish flesh were detected in years when *Alexandrium* spp. and *Dinophysis* spp. were more prevalent (Esenkulova et al., 2021)

Alexandrium

- Spatial patterns
- Temporal patterns
- Statistically significant interannual and seasonal relationships (Esenkulova et al., 2021)

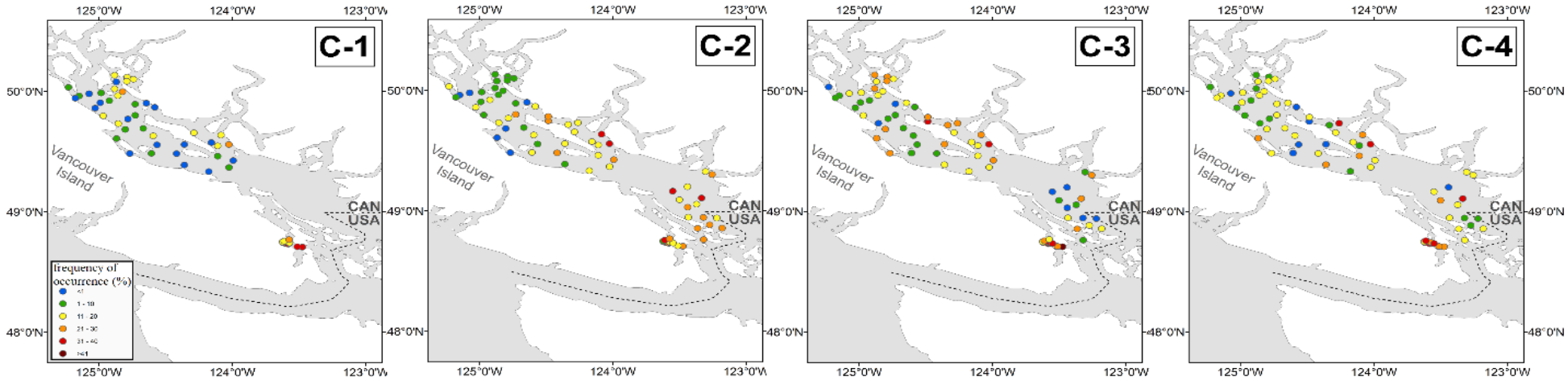
Intra-annual (monthly mean) relationships

Secchi depth	**-0.497**
Temperature	**0.753**
Salinity	-0.363
Stratification	**0.611**
Nitrate	**-0.651**
Phosphate	**-0.557**
Silicate	-0.205
Wind Speed	-0.174
Rainfall	**-0.505**
Cloud Cover	**-0.653**
Fraser River Flow	0.33

Inter-annual relationships

Temperature	**-0.143**
Salinity	**0.169**
Stratification	**-0.14**
Secchi	0.106
N	0.058
P	0.023
N:P	0.058
Si	**-0.036**

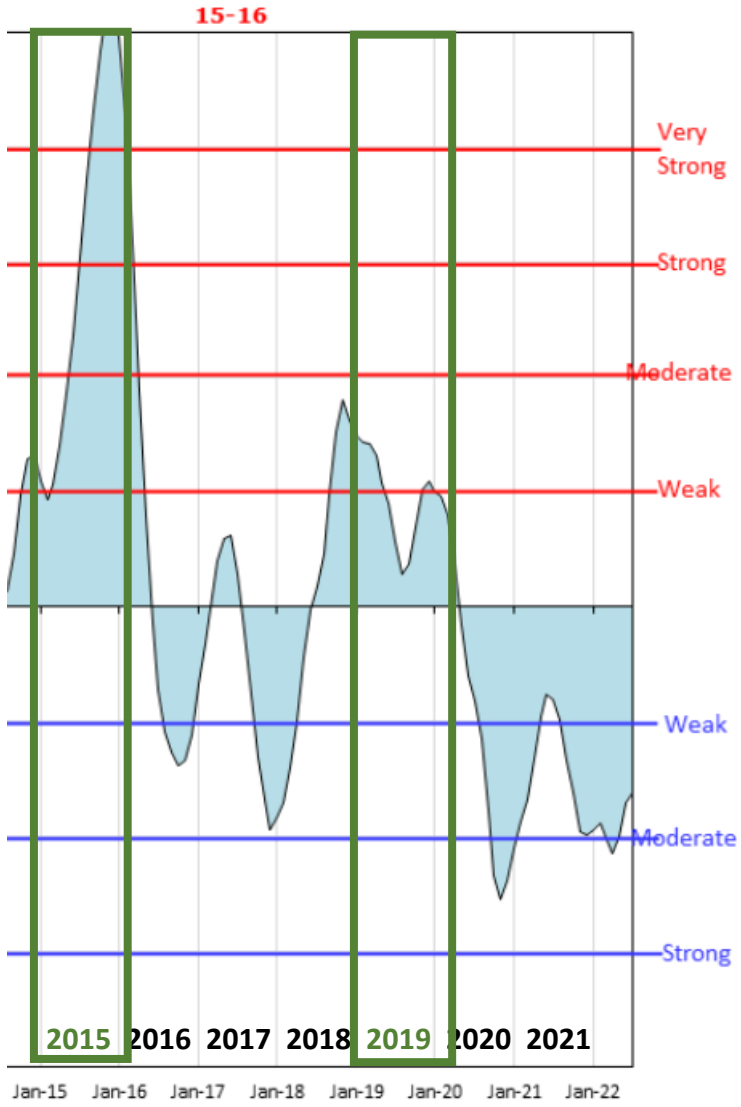
Average annual frequency of occurrence (%) of Alexandrium *spp.*



Annual *Alexandrium* occurrence vs ENSO

% of surface samples containing algae, March-September, 4 areas: BS, CB, IS, PR

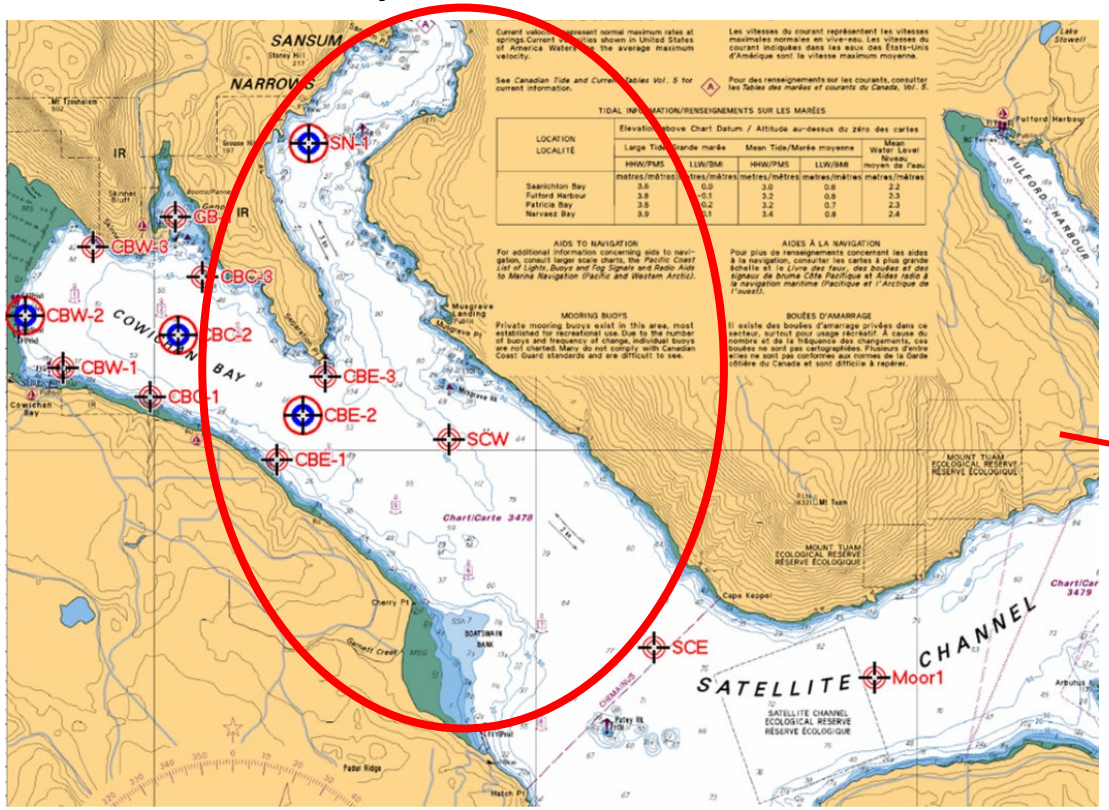
Year	Alexandrium	Dinophysis	ENSO
2015	15.2	2.1	very strong **El Nino**
2016	19.2	0.5	very strong El Nino/weak La Nina
2017	21.4	1.8	weak La Nina
2018	19.6	5.7	weak La Nina
2019	14.6	4.1	weak **El Nino**
2020	21.1	3.4	moderate La Nina
2021	20.6	6.7	moderate La Nina

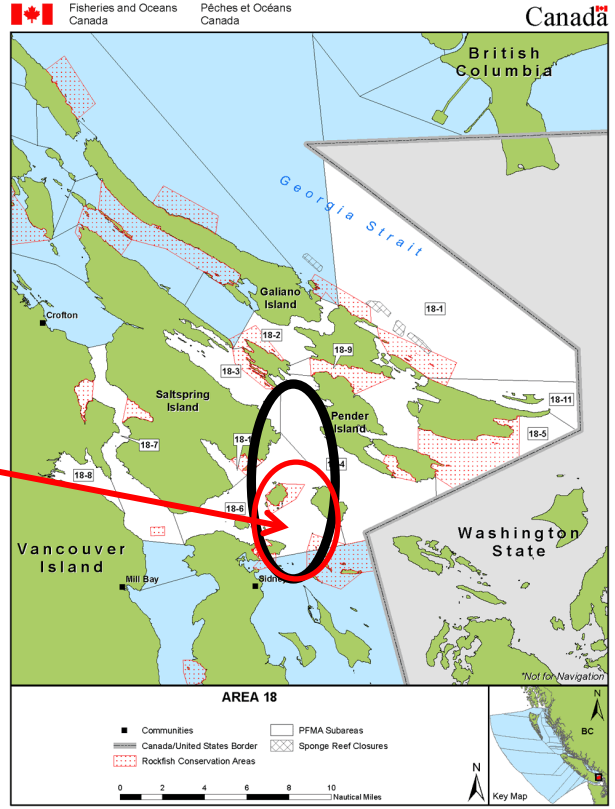


In situ *Alexandrium* spp. and Paralytic Shellfish Poisoning toxins

Example of the results is based on DFO management area 18-7

Cowichan Bay





PSP-total ug STXdiHCl

All shellfish species (blue mussel, geoduck, oyster), all tissues (meat, viscera)

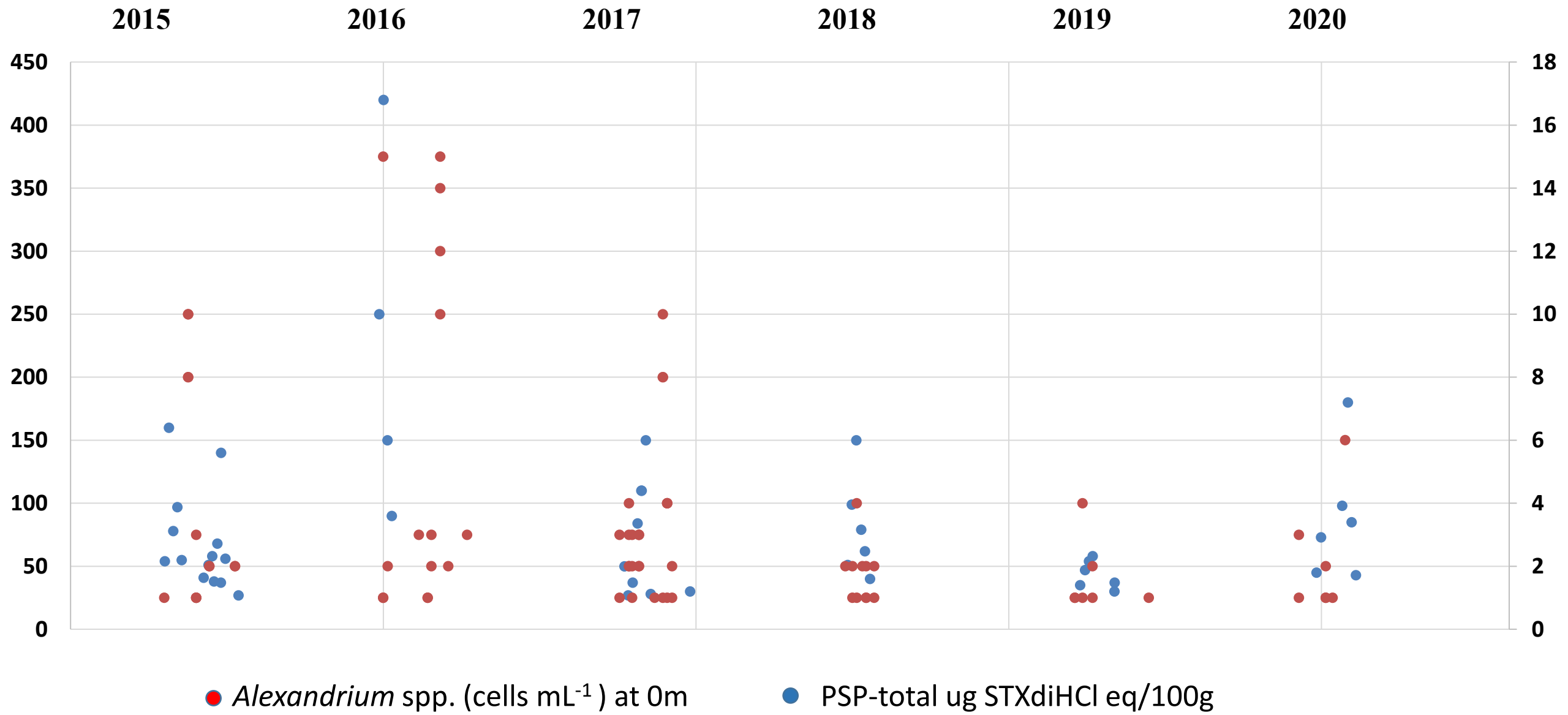
PACIFIC SALMON FOUNDATION

Citizen Science water samples ~ twice a month, CBE2, CBC2, SCE, SCW

CFIA

Shellfish samples ~ weekly

Alexandrium in water column and PST in shellfish flesh, DFO area 18-7, April - Octobe



Summary

- Based on 8 years of high resolution monitoring in the Strait of Georgia (>1000 samples a year), annual *Alexandrium* occurrence was lower by ~ 25% in El Nino years compared to non El Nino years
- *Dinophysis* annual occurrence varied ten fold (from 0.5 to 6.7); synchrony with spring *Noctiluca* blooms
- Analysis of 4 years data revealed negative annual links of *Alexandrium* to temperature, stratification, and silica; positive with salinity. Seasonally it had positive links to temperature and stratification, negative to nitrates, cloud cover, phosphates and secchi depth
- Agreement between annual cell occurrence and max toxins in the Strait; *Alexandrium* cell counts in water and PSP toxins in shellfish in Cowichan Bay
- There is a critical need for more harmful algae research in Canada