Linking harmful algal blooms and oceanographic conditions in the Strait of Georgia, Canada

Svetlana Esenkulova, Karyn Suchy, Rich Pawlowicz, and Isobel Pearsall

PACIFIC SALMON FOUNDATION

SALISH SEA MARINE SURVIVAL PROJECT

University of Victoria

ODL OCEAN DYNAMICS LABORATORY

UBC

OCEAN NETWORKS CANADA

Citizen Scientist Program 2015 - 2017

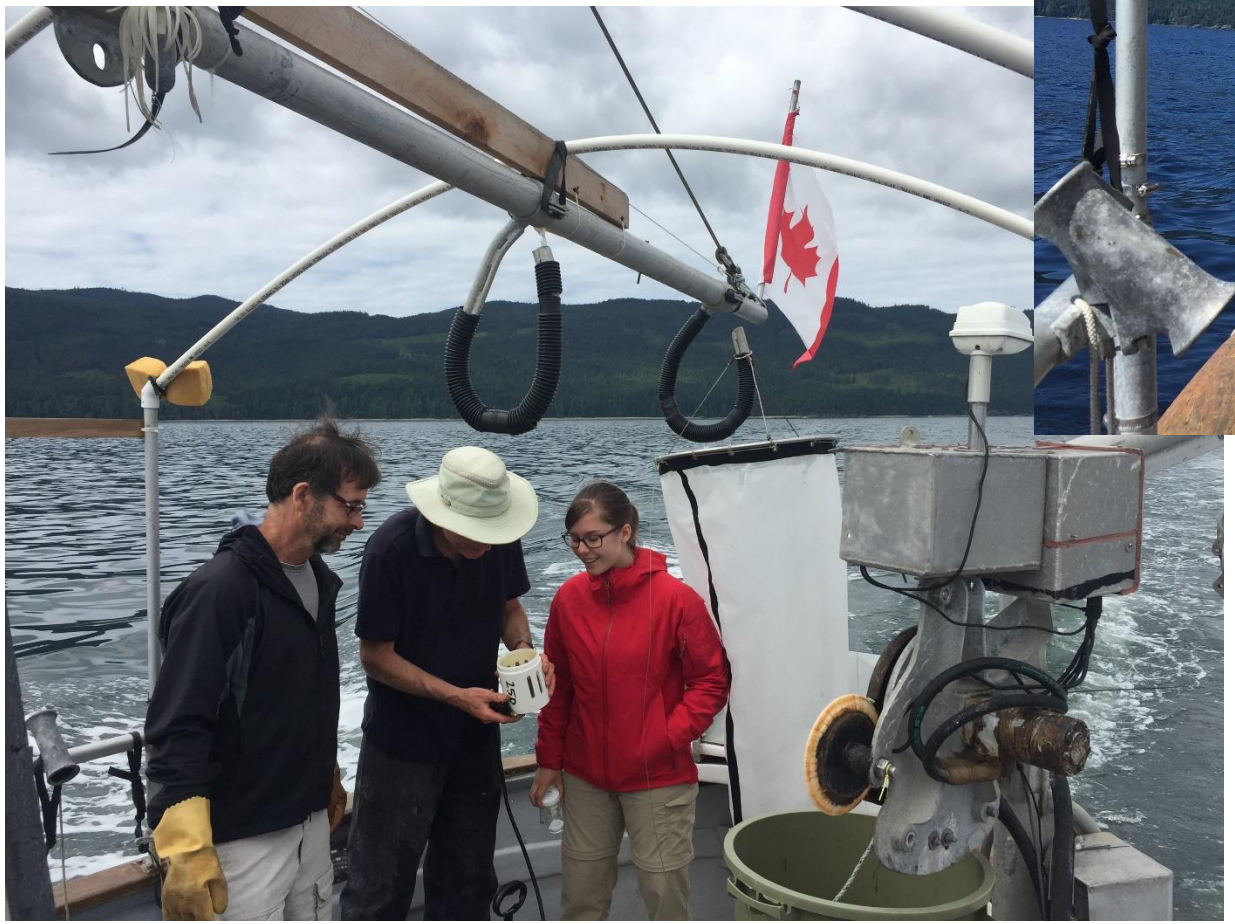
- Citizen science is defined as *"scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions"*

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

unique data on entire Strait of Georgia

Isobel Pearsall – S9 (Oak Bay-2) 14:20

Citizen Scientists

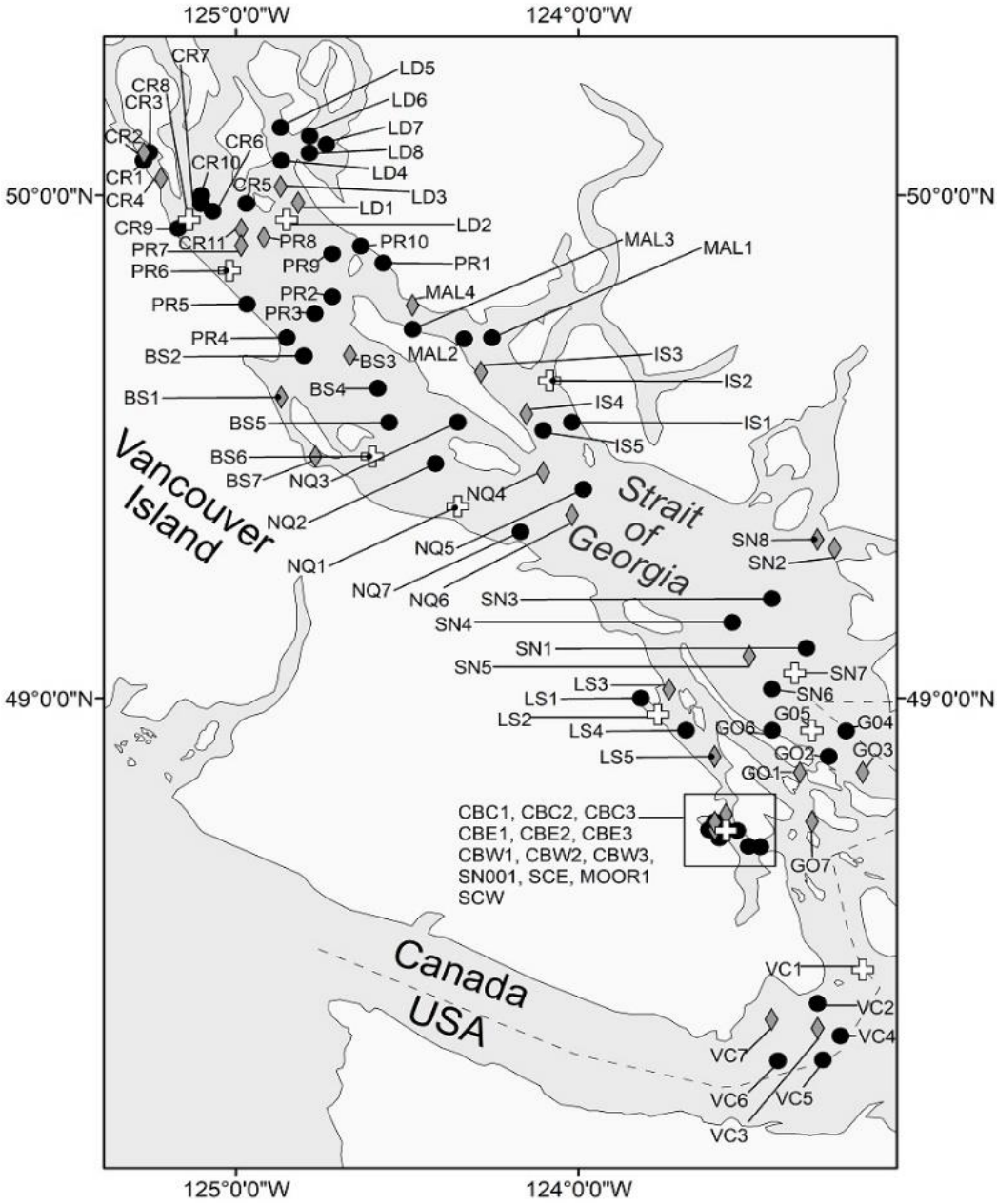


Citizen Science 2015 - 2017

Physical and chemical parameters >5000 CTD casts
>65 stations consistently sampled in 3 years
temperature, salinity, density, fluorescence, oxygen,
Secchi ~7700 reading

Nutrients >3000 samples
10 stations at 0 and 20 m
nitrate+nitrite, silicate, phosphorus

Phytoplankton >5000 samples
80 stations at the surface 0m
10 stations at 0, 5, 10, 20 m

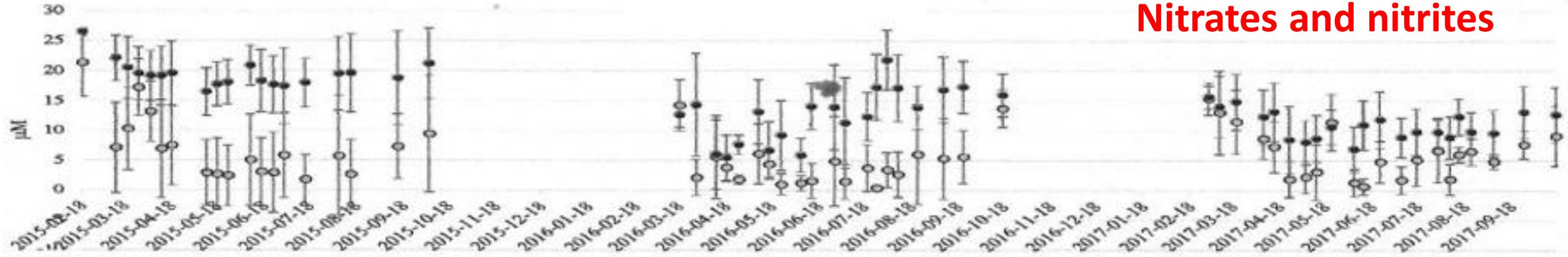


Sample analysis

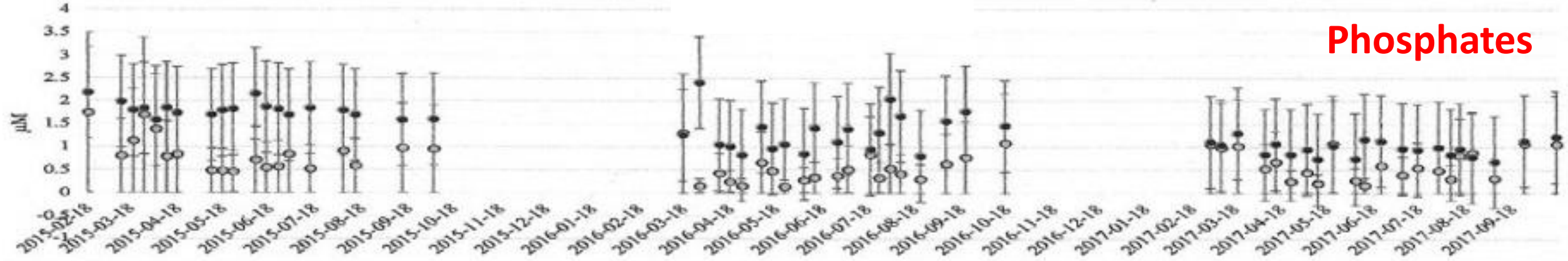
- Water samples for nutrients analysis from 2015 were analyzed at the Institute of Ocean Sciences, DFO, using SEAL Autoanlyser; 2016 and 2017 were analyzed at UVic following QuikChem® Methods; results of nutrient analysis were verified and compiled at the Ocean Dynamics Laboratory, UBC.

- Water samples for phytoplankton analysis were preserved with Lugol's Iodine and analysed on Sedgewick-Rafter slide with a compound light microscope following the method developed by Dr. I. Whyte and N. Haigh for the Harmful Algae Monitoring Program

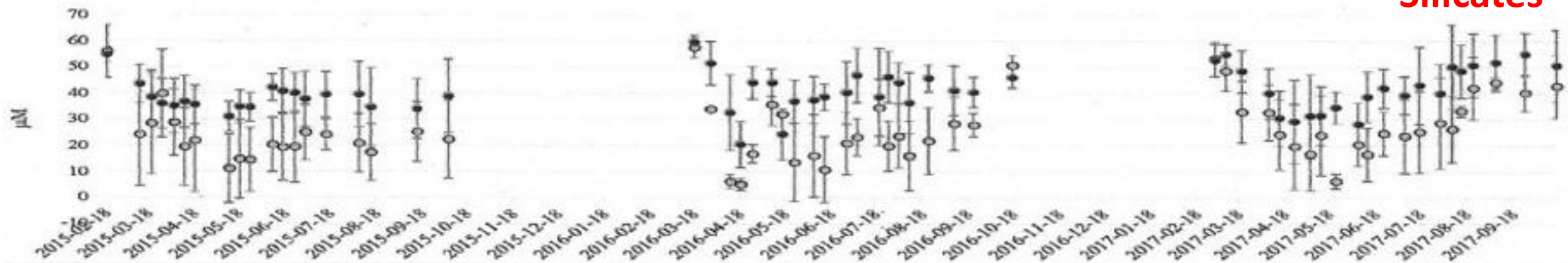
Nitrates and nitrites

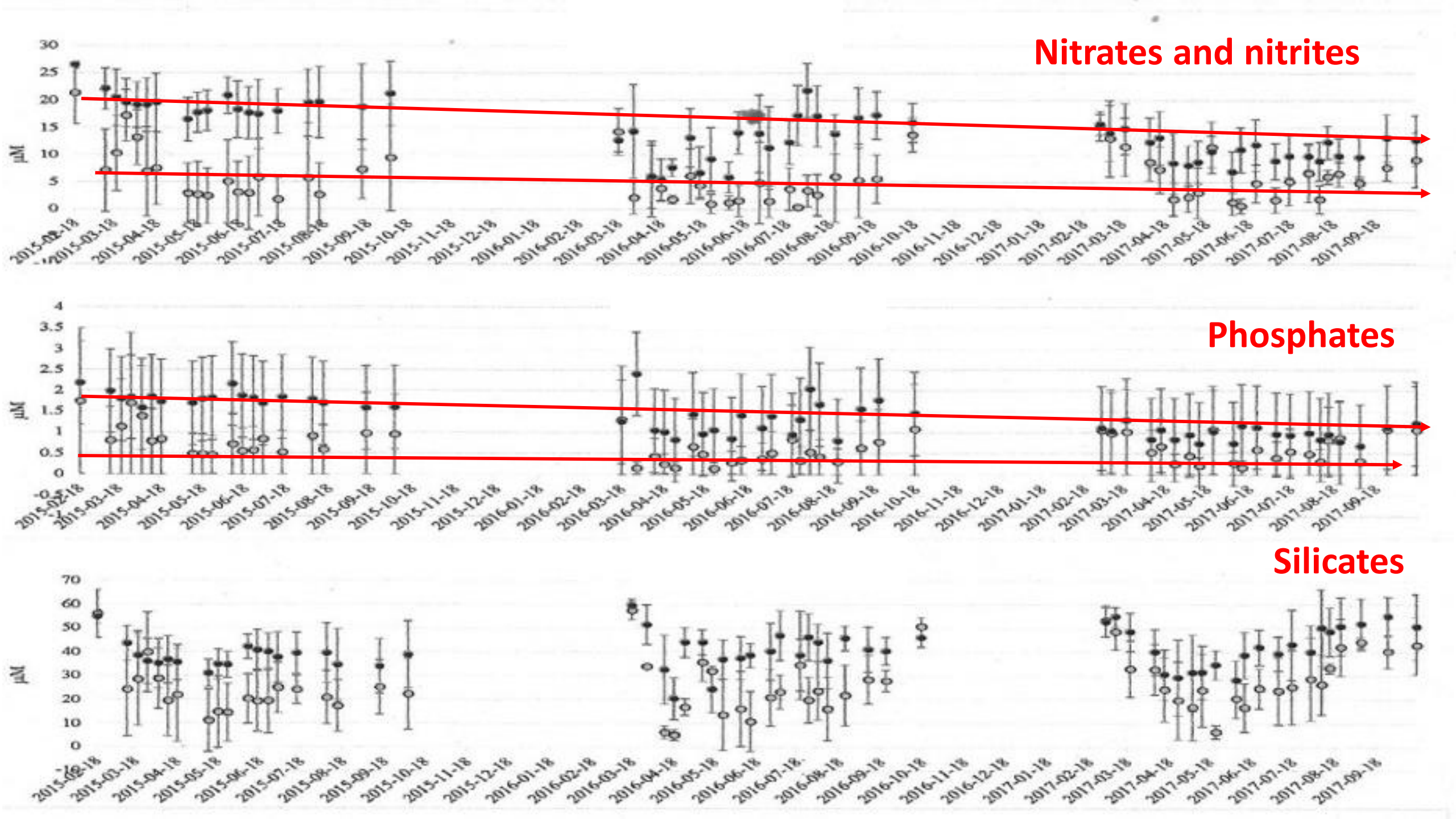


Phosphates

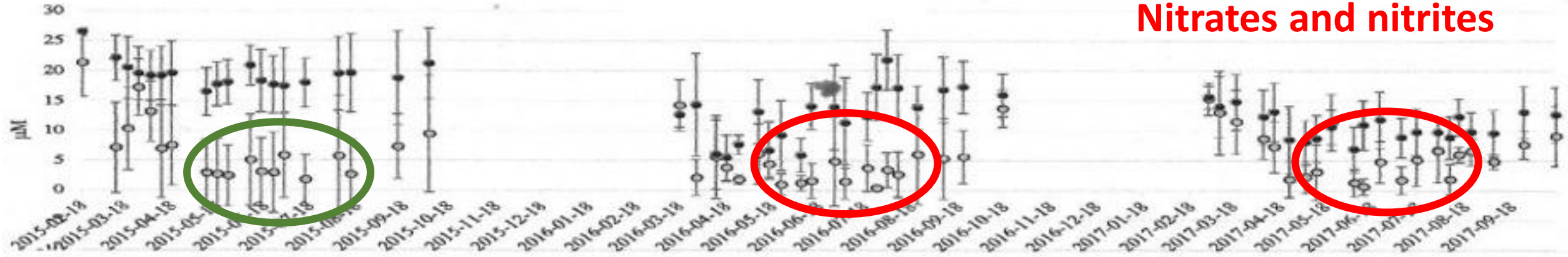


Silicates

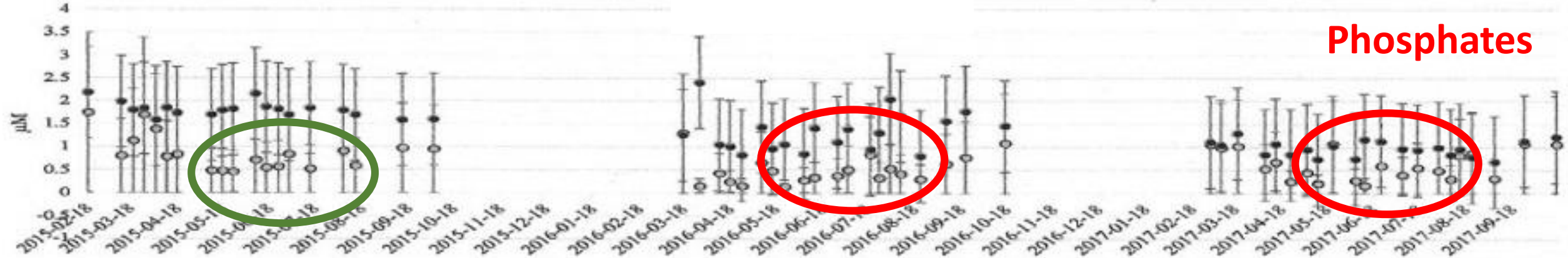



Nitrates and nitrites
Phosphates
Silicates
µM

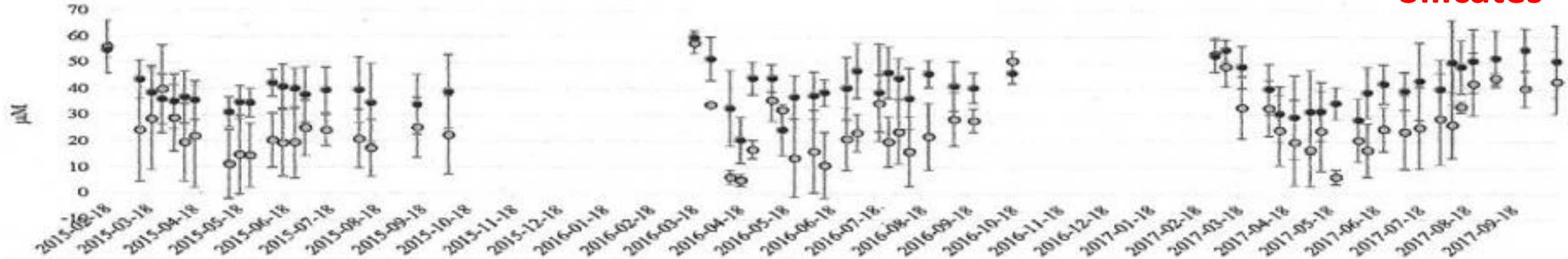
Nitrates and nitrites



Phosphates

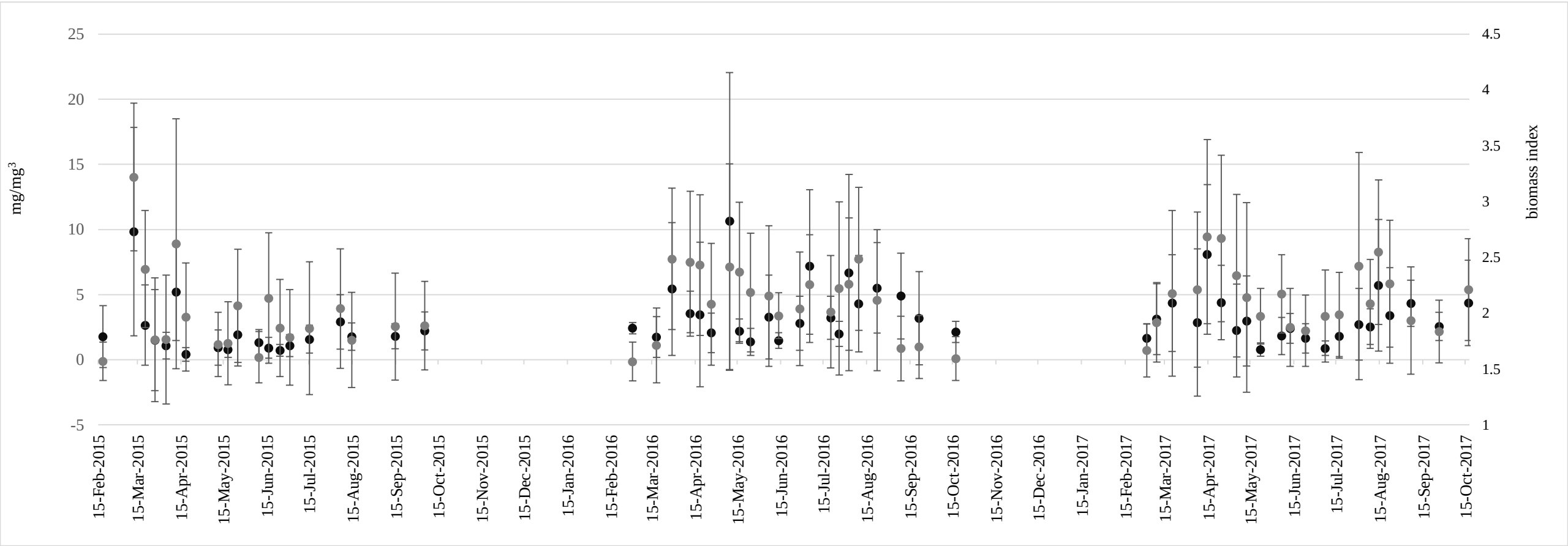


Silicates



Phytoplankton

- Mean chl-a at 1 m (black marker) and *in situ* biomass index at 0 m (grey marker)



Phytoplankton

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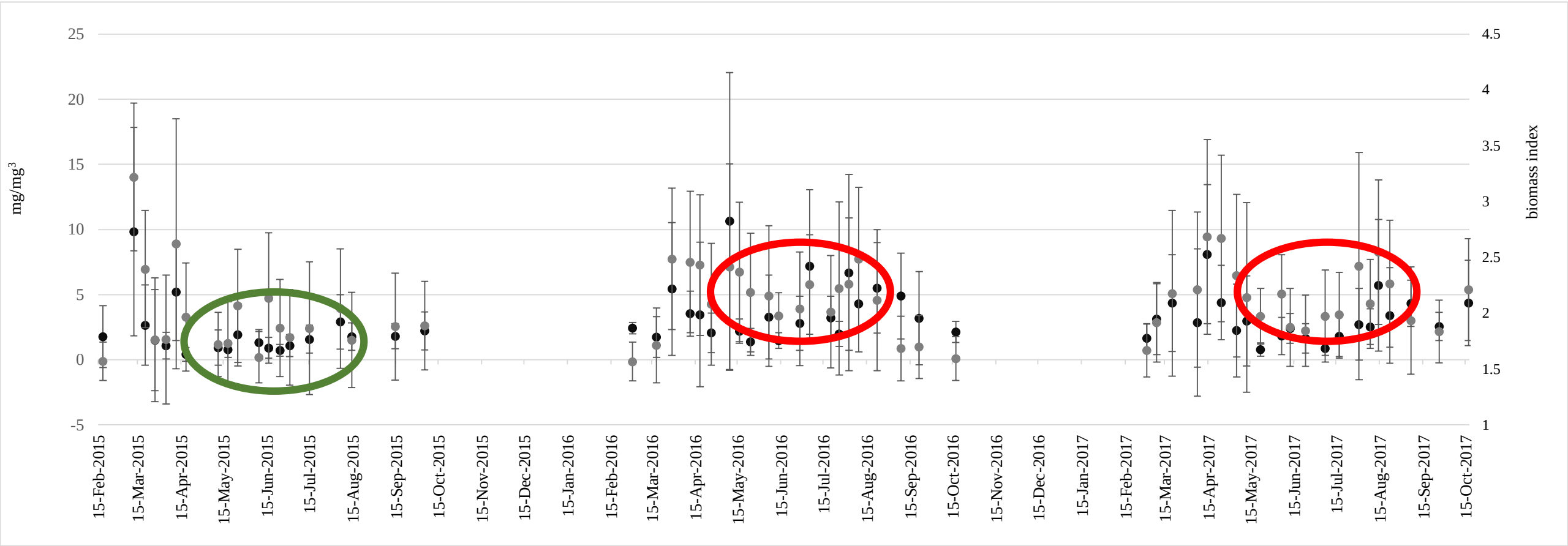
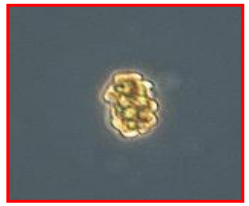
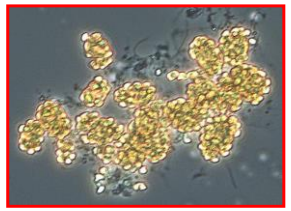


Harmful Algae Negatively Impacting Finfish Aquaculture in British Columbia

Photographs of algal species that produce toxins harmful to fish are framed with red; species that are mechanically harmful are framed in green; other – purple.

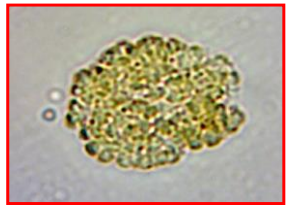
Raphidophyceae

Heterosigma akashiwo

15-40 µm

***Chattonella* sp. (live in the left image)**

30-70 µm

Dictyochophyceae

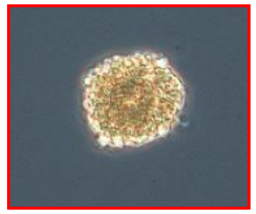
Dictyocha speculum

25-50 µm

D. fibula

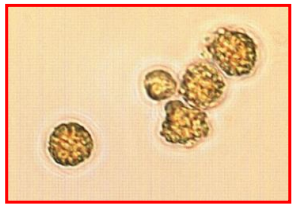
25-50 µm

Non-skeletal *Dictyocha*



25-65 µm

***Pseudochattonella* sp.**



(live cell)

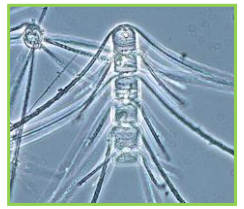
20-70 µm

***Pseudopedinella* sp.**

3-9 µm

Bacillariophyceae

Chaetoceros concavicorne

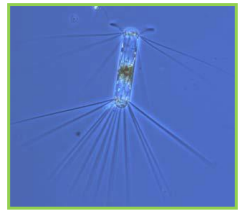


12-30 µm (valve)

C. convolutus

10-27 µm (valve)

Corethron hystrix



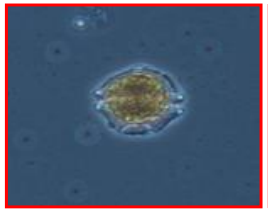
100-250 µm

Rhizosolenia setigera

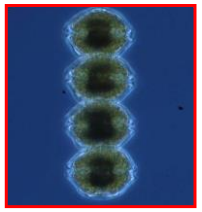
200-1000 µm

Dinophyceae

***Alexandrium* sp.**

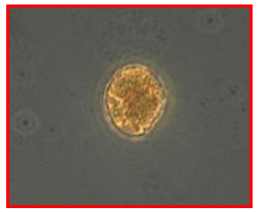
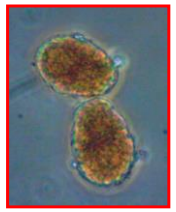


A. catenella



20-50 µm

Cochlodinium fulvescens

25-40 µm

Karenia mikimotoi

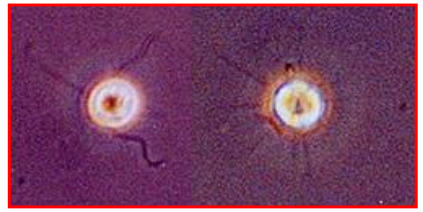
18-37 µm

Noctiluca scintillans

200-2000 µm

Prymnesiophyceae

***Chrysochromulina* spp. (live cells)**



5-15 µm

Funding provided by: Fisheries and Oceans Canada, Aquaculture Collaborative Research and Development Program

Produced by: Nicky Haigh and Svetlana Esenkulova of Microthalassia Consultants Inc. and Dr. Chris Pearce and Laurie Keddy of Fisheries and Oceans Canada

Note: All algae cells preserved with Lugol's iodine (unless otherwise stated).

MICROTHALASSIA

Fisheries and Oceans Canada | Pêches et Océans Canada

Percent of samples containing harmful algae, average in all samples and maximum concentration (cells mL^{-1}) recorded in different years in the surface (0 m) samples.

	Abundance (%)				Avg. concentration				Maximum concentration			
	2015	2016	2017	total	2015	2016	2017	total	2015	2016	2017	total
Dictyocha spp.	3.6	25.1	26.7	20	0.1	6.4	9.7	5.9	5	450	400	450
Rhizosolenia setigera	6.9	20.2	18.1	15.9	1.1	13.8	19.5	12.5	250	800	1800	1800
Alexandrium spp.	10.7	16.3	18.1	15.4	0.3	0.4	0.3	0.4	18	15	10	18
C. convolutus and C. concavicornis	10	1	4.5	4.7	0.5	0	0	0.2	19	8	20	20
Heterosigma akashiwo	1.1	7.4	2.9	4.1	0	1	0.2	0.4	6	150	20	150
Dinophysis spp.	1.7	0.7	1.6	1.3	0	0	0	0	2	4	5	5
Cochlodinium fulvescens	0.5	1.3	0.9	0.9	0	0	0	0	5	6	2	6
Noctiluca scintillans	0.3	0.6	0.7	0.5	0	0	0	0	1	2	2	2

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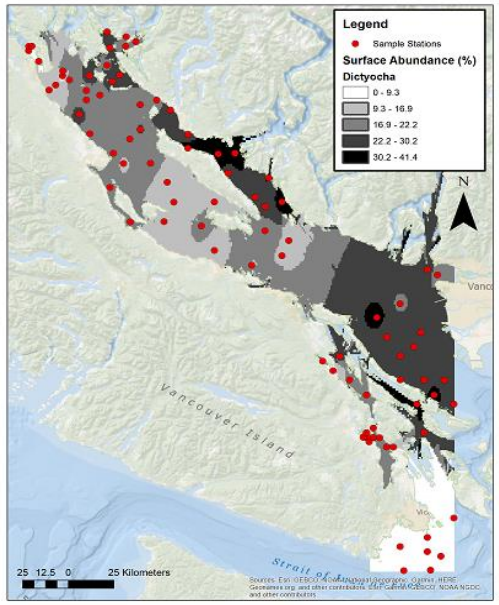
Noctiluca scintillans	0.3	0.6	0.7	0.5	0	0	0	0	1	2	2	2

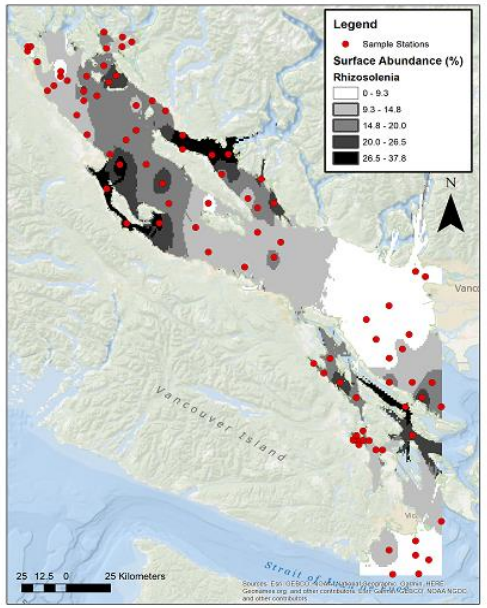
Environmental niches

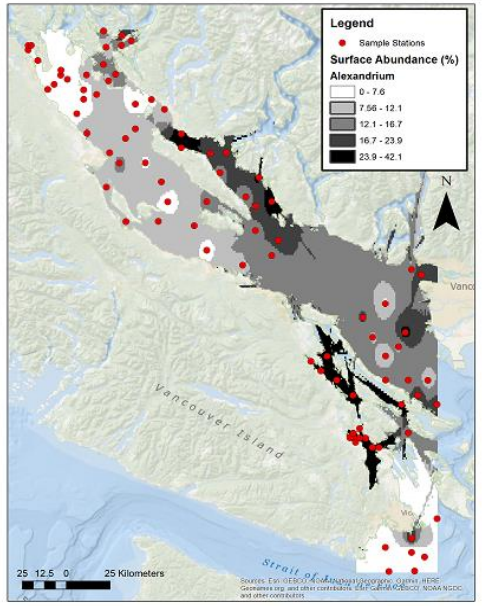
	Temperature (℃) at 1 m					Salinity (ppt) at 1 m					Stability index				
	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD
Dictyocha spp.	554	6.51	21.52	16.11	3.27	554	1.50	31.46	24.33	4.34	531	0.01	9.57	2.75	1.88
R. setigera	452	6.87	22.10	16.00	2.96	452	7.02	31.57	25.23	3.77	444	0.01	9.64	2.35	1.77
Alexandrium spp.	429	7.02	22.09	14.74	3.36	429	7.04	31.71	24.85	4.25	419	0.01	9.64	2.20	1.91
C. convolutus and C. concavicornis	152	6.42	19.99	11.01	3.14	152	15.10	31.75	27.20	1.94	145	0.01	4.19	1.00	0.87
H. akashiwo	120	11.28	20.72	16.21	2.39	120	6.24	31.4	25	4.5	120	0.10	10.55	2.65	2.09

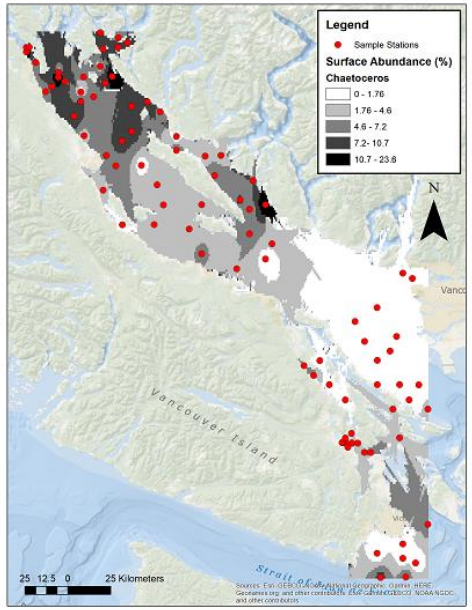
	Nitrate and nitrite					Phosphates					Silicates				
	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD	N	Min.	Max.	Mean	SD
Dictyocha spp.	307	0.00	32.17	2.23	4.75	307	0.00	3.53	0.68	2.51	308	0.00	82.53	13.18	17.39
R. setigera	243	0.00	24.64	1.92	3.73	243	0.00	3.40	0.33	0.63	243	0.00	55.90	7.63	12.43
Alexandrium spp.	212	0.00	32.17	2.36	4.74	212	0.00	3.35	0.36	0.87	207	0.00	80.40	19.16	21.49
C. convolutus and C. concavicorne	31	0.00	22.49	7.30	7.23	31	0.00	2.06	0.66	0.62	31	0.00	56.33	21.74	20.16
H. akashiwo	72	0.00	20.40	1.86	3.69	72	0.00	7.44	0.48	1.23	72	0.00	42.20	6.34	12.06

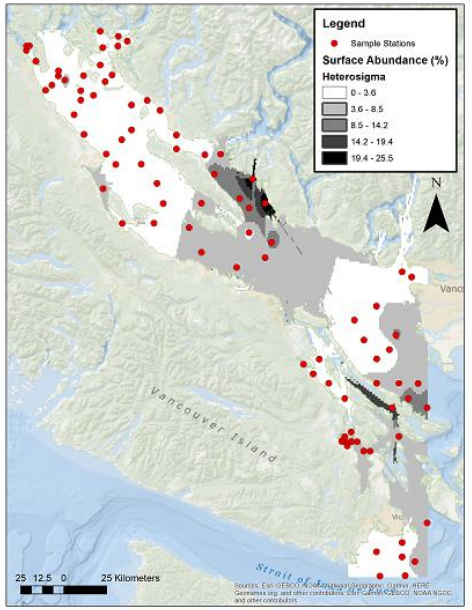
Spatial distribution - mean 3 year abundance









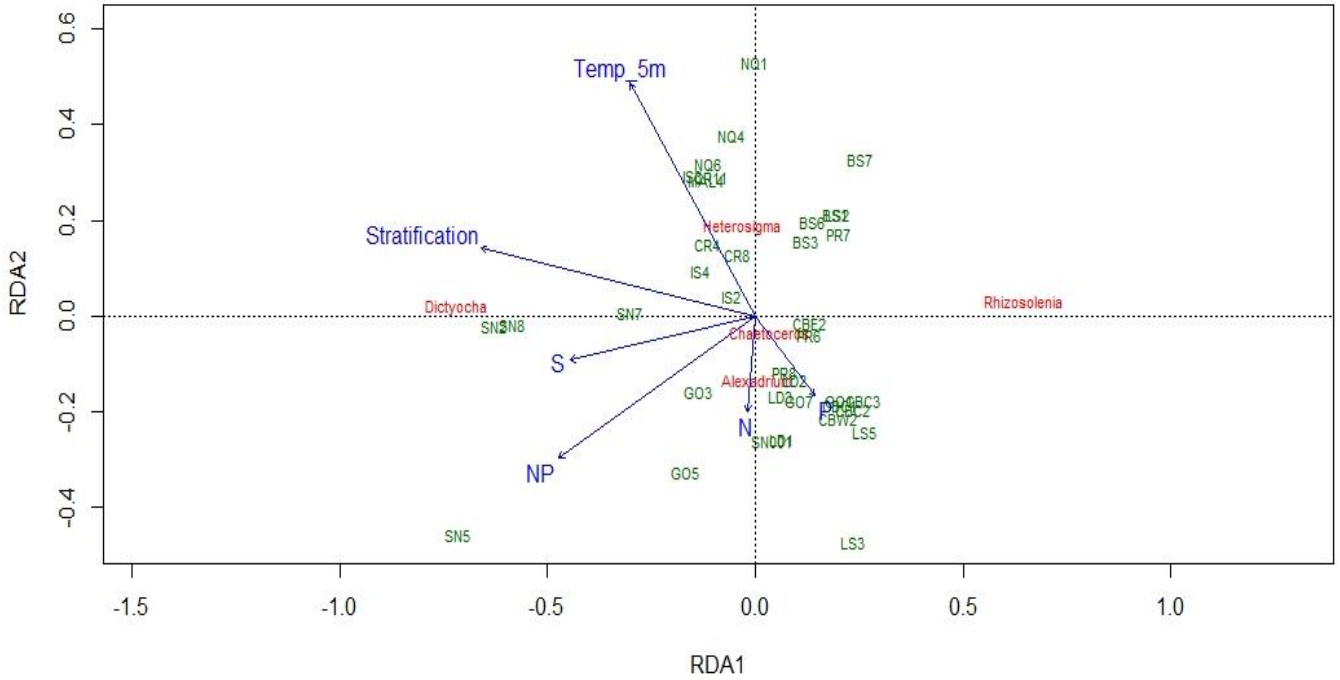


Dictyocha ***R. setigera*** ***Alexandrium*** ***C. con.+concav.*** ***H. akashiwo***

Maps by Ben Skinner, PSF
inverse distance weighted interpolation, Jenks natural optimization breaks

Statistical Analyses - Spearman rank order, RDA

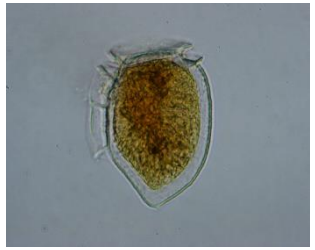
	Environmental Drivers				Nutrients			
	Temperature	Salinity	Stratification	Secchi	N	P	N:P	Si
Dictyocha	**0.286**	**-0.466**	**0.442**	**-0.356**	0.307	0.170	**0.338**	0.065
Rhizosolenia	0.099	0.023	-0.078	**-0.313**	0.045	0.021	-0.156	**-0.437**
Alexandrium	-0.027	-0.081	0.017	**-0.333**	0.191	0.253	0.010	-0.106
Chaetoceros	-0.163	0.178	-0.168	0.110	0.203	0.159	0.139	-0.066
Heterosigma	**0.222**	-0.163	0.171	**-0.211**	-0.053	-0.020	-0.138	-0.131



Dictyocha abundance was positively correlated with stratification, negatively with salinity

Significant relationships between *Dictyocha* and N:P ($r_s = 0.338$)
R. setigera and Si ($r_s = -0.437$).

Harmful algae and toxins (CFIA)

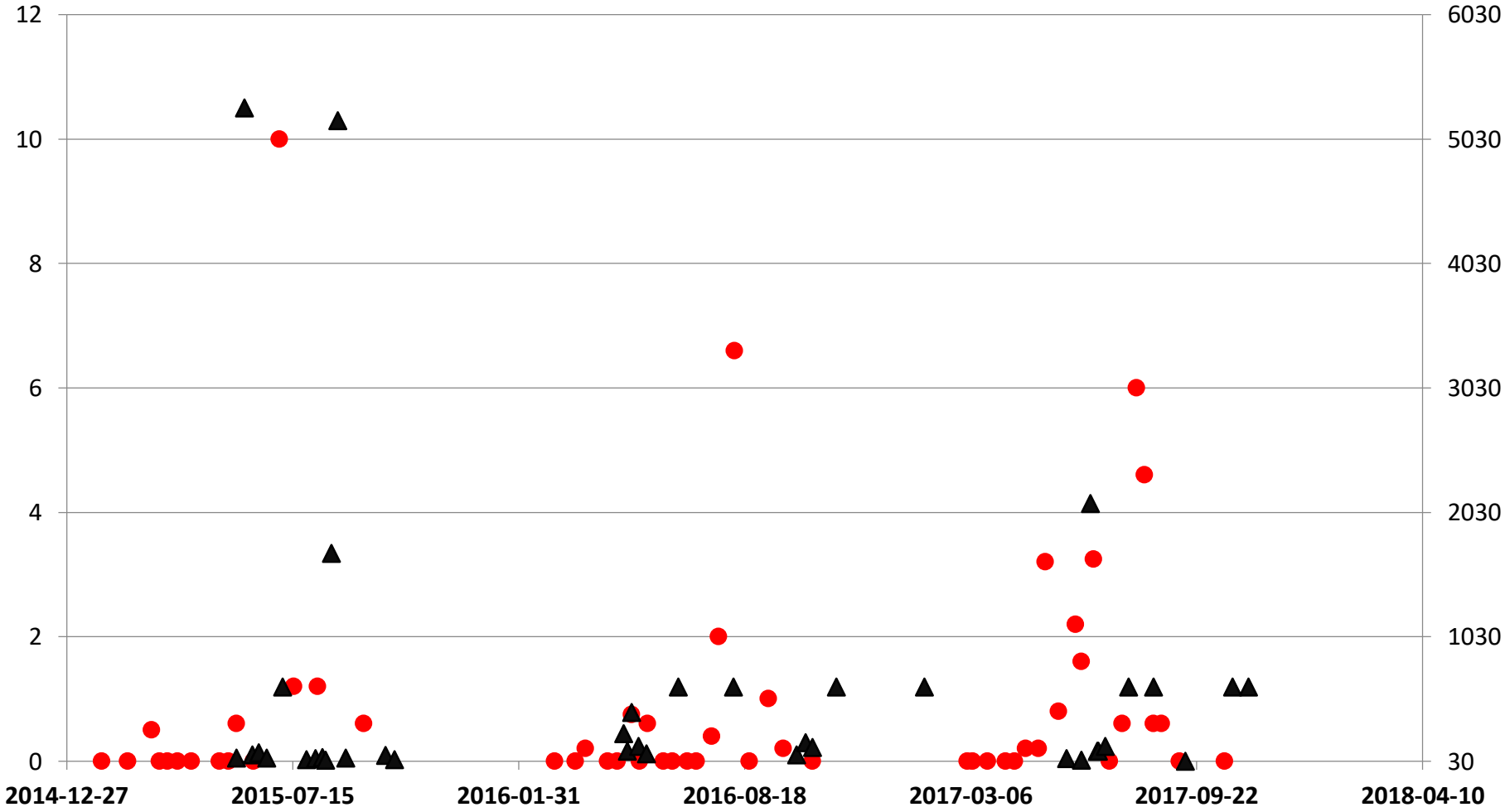


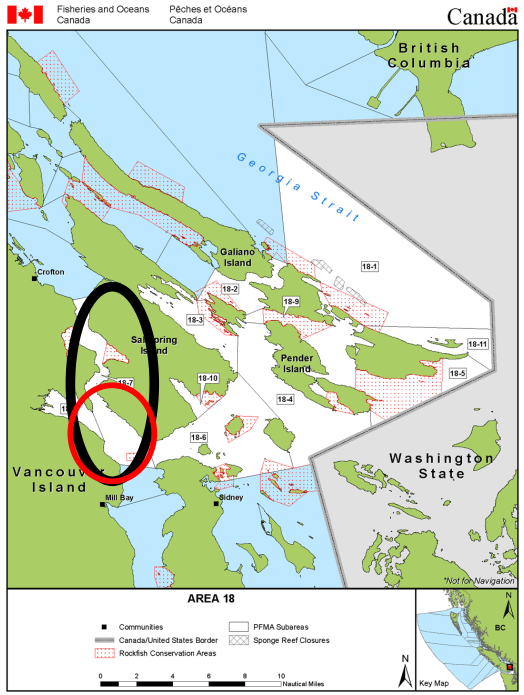
Mean cell abundance and maximum toxin concentrations

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

years these algae were more abundant there were higher toxin levels accumulated in shellfish flesh.

Alexandrium spp. and Paralytic Shellfish Poisoning toxins, area 18-7





Citizen Science water samples
~ twice a month

CFIA shellfish samples
~ weekly/bi-monthly

● *Alexandrium* spp. (cells mL^{-1}) at 0m PSP-total ug STXdiHCl eq/100g (left axis)

Summary

- Citizen Science is an efficient way to collect measurements and samples
- There were strong interannual and spatial variations (env. + phyto) in SoG
- It appears phytoplankton was not nitrate/phosphate limited in summer 2015
- Several statistically significant relation of harmful algae and environmental data were found
- Relationship between HAB dynamics and coastal water conditions are convoluted and long term results are needed to establish links to climate change

Photo by Michael Bahrey